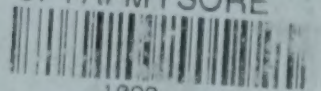


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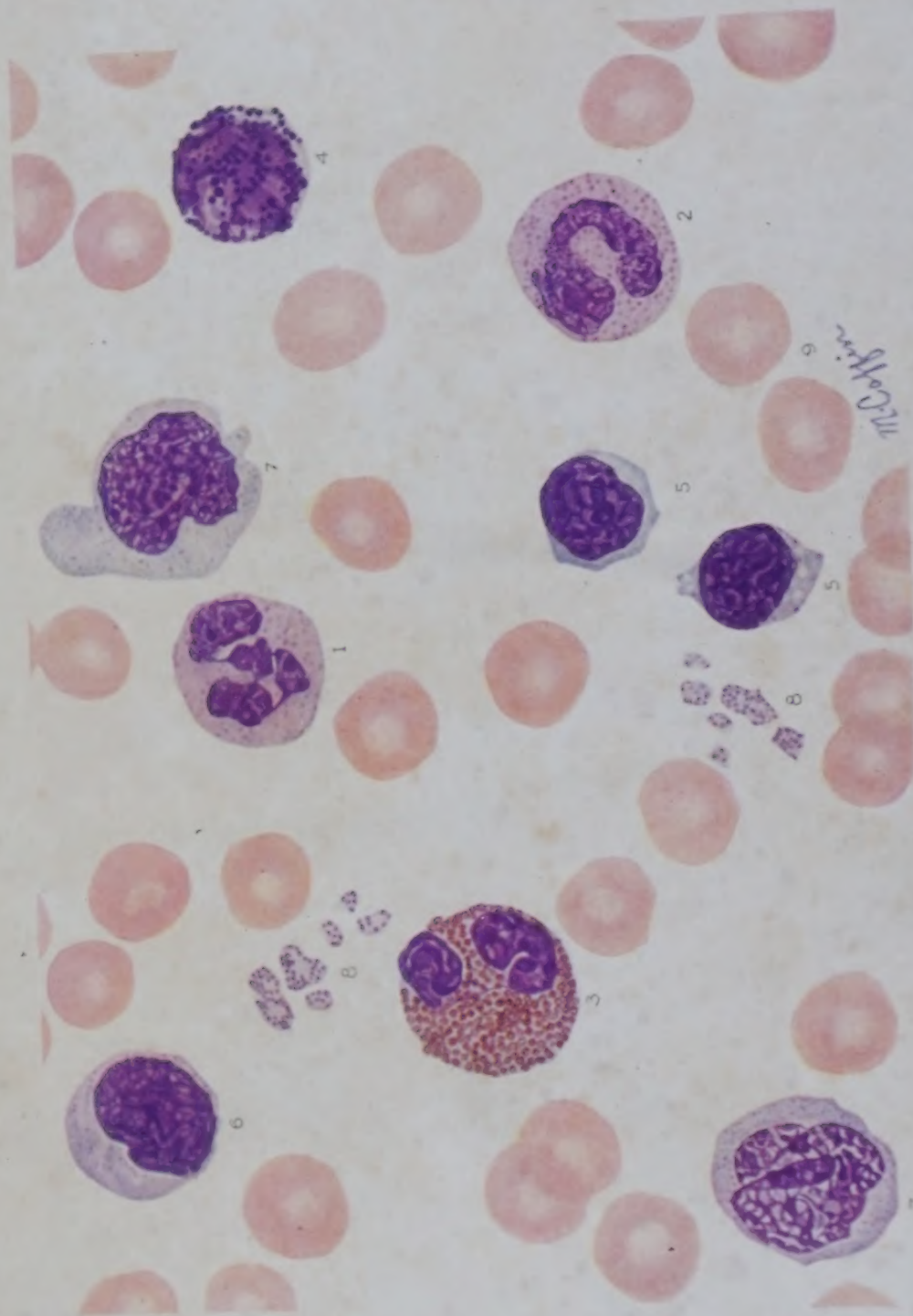
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1. circulatory system
2. blood cellular elements
3. blood 4. digestive system
5. nervous system (16) nutrition
6. Urinary system (17) teeth
7. ~~male~~ genitalia (18) saliva.
- ~~female~~ skeleton
- skeletal muscles
- skin 11. eye 12. ear 13. nose
- endocrines 15. metabolism

Thy







Normal cellular constituents of adult human blood. 1, Segmented (polymorphonuclear) neutrophil; 2, band (stab) neutrophil; 3, segmented eosinophil; 4, basophil; 5, small lymphocyte; 6, large lymphocyte;

# NORMAL VALUES IN CLINICAL MEDICINE

By

F. WILLIAM SUNDERMAN, M.D., Ph.D.

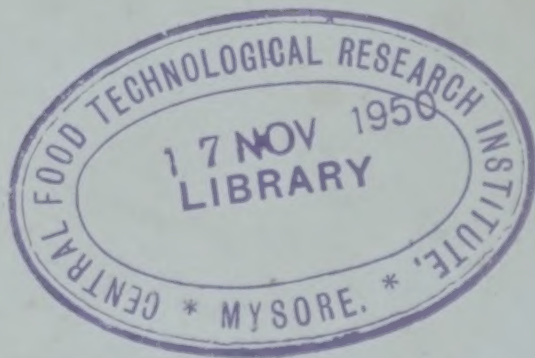
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## FOREWORD

IT IS GOOD PRACTICE to use the term "norm" for that selected range of values which can be accepted as a standard, and to use the adjective "normal" for any measurement which falls within the "norm."

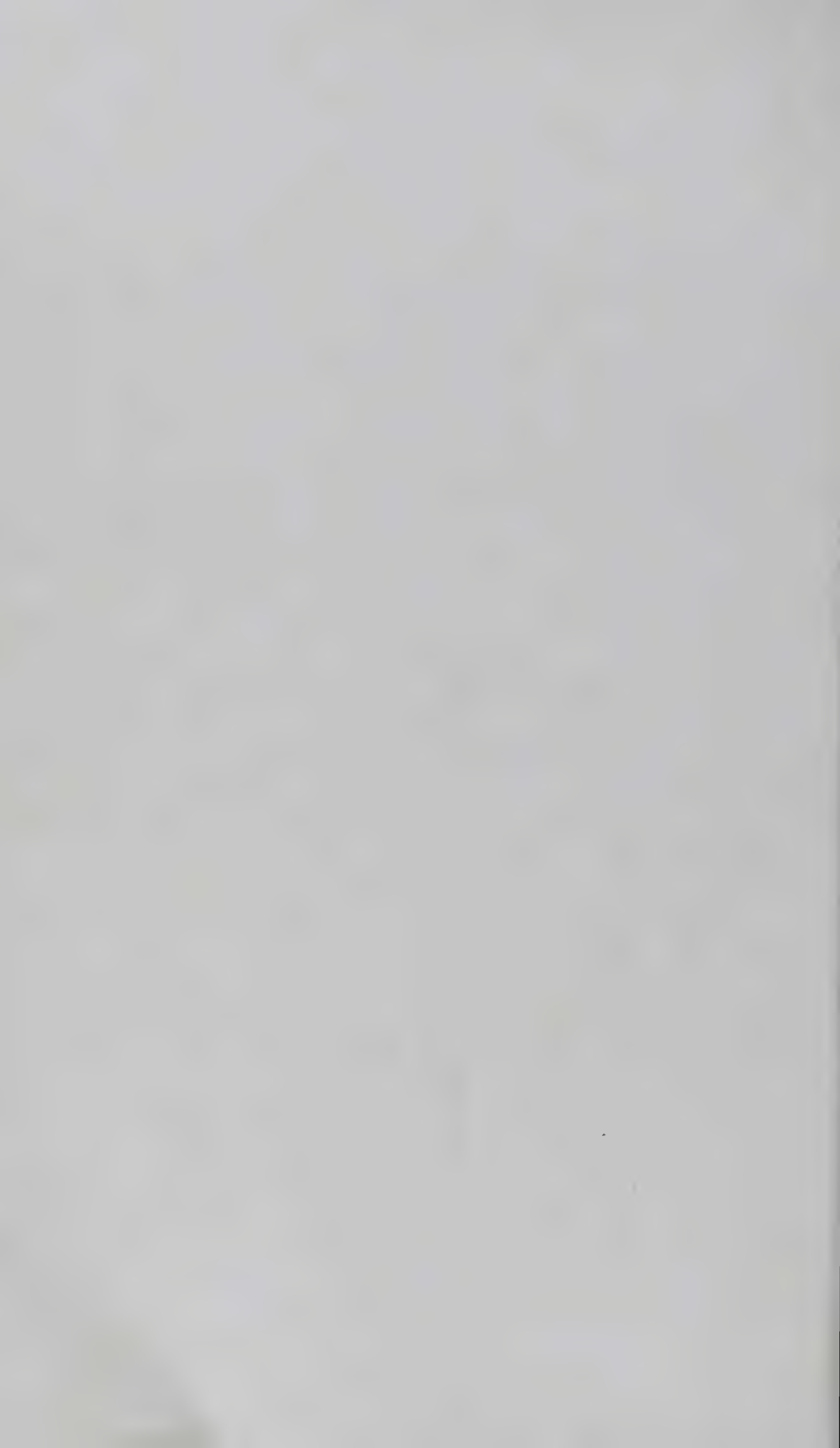
To establish a "norm" requires the selection of a sufficiently large group of subjects who, on other criteria than the measurement under consideration, can be considered as typical healthy persons, and the choice of a method of selecting an appropriate segment of the distribution within the group of values or the measurements in question.

Persons are commonly considered normal when they appear healthy and free from any disability or disease which may be expected to modify the measurement in question. It is recognized, with respect to some measurements, that the norm for healthy persons varies with age, sex, race or diet, altitude, climate or other environmental conditions.

For some measurements, published data on a large series of apparently healthy subjects, perhaps classified by sex, age and race, are available. The range that includes some fraction of the distribution has sometimes been advocated as the "norm" when such data are available.

For most measurements we are dependent upon the range commonly found in hospital experience in patients whose condition justifies no suspicion of abnormality of the measurement in question. In such cases the range selected is often rather arbitrarily chosen to include most supposed normals and to exclude most supposed abnormals. "Norms" so selected and published gain acceptance when they conform to the experience and judgment of other workers.

J. HAROLD AUSTIN, M.D.



## PREFACE

"WHEN YOU CAN measure what you are speaking about and express it in numbers, you know something about it; when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind" (Lord Kelvin).

\* \* \* \* \*

The various connotations attached to the word "normal" frequently result in a confusion of concepts. The sense in which the term is used in this book has been defined in the Foreword.

Workers in the fields of medicine and allied sciences are always concerned with the need for ascertaining or determining values and characteristics that constitute the "norm." Although this need has been clearly recognized, practically no attempt has ever been made to select and assemble such pertinent data into a comprehensive unit. The authors proceeded with this need in mind.

In accordance with the definitions established in the Foreword, the pioneering purpose of this book is to present a discussion and compilation of values which may be termed "normal." The authors ventured to hope that the book might thus serve as a criterion and a source of convenient reference for students and workers in the broad fields of clinical medicine. Data, selected and condensed from relevant literature on the advice of collaborators, have been included in certain instances because they seemed to be the only authoritative measurements available, meager though they be. In addition, it should be noted that the investigator in medicine often finds that he cannot arrive at a range of values which can be accepted as standard and must be content with average values, although these may prove eventually to be inconclusive in their significance. To consider such average values as "normal" has sometimes led to semantic confusion. We suggest that the reader evaluate and interpret the tabulations and figures included in the text in the light of his own experience, and that he consult the original sources noted in the bibliography.

Special efforts have been made to select reliable data and to interpret and record them accurately. In view of the insidious ways in which errors are prone to intrude, it would be noteworthy, indeed, if our efforts toward these ends were successful throughout. Critical comment regarding errors of omission or commission, as well as suggestions for improvements or refinements, will be received with respect and appreciation.

A section has been added which includes certain information, such as statistical methods, actuarial tables, food values, and the like, that cannot be considered "norms." These inclusions are made for the reader's convenience rather than for their essential pertinency.

The surviving author (F. W. S.) takes this opportunity to pay tribute to the memory of his esteemed friend and colleague, Dr. Frederick Boerner. Dr. Boerner's intense desire to advance the standards of the medical and allied

professions and his enthusiastic support and valuable contributions aided materially in the development of this work.

The help and guidance given the authors by their Collaborators, by Miss Irene Orchard and Mrs. Eleanor Warner through their secretarial assistance, and by the W. B. Saunders Company, are gratefully acknowledged.

F. WILLIAM SUNDERMAN

*Cleveland, Ohio*  
*September, 1949*

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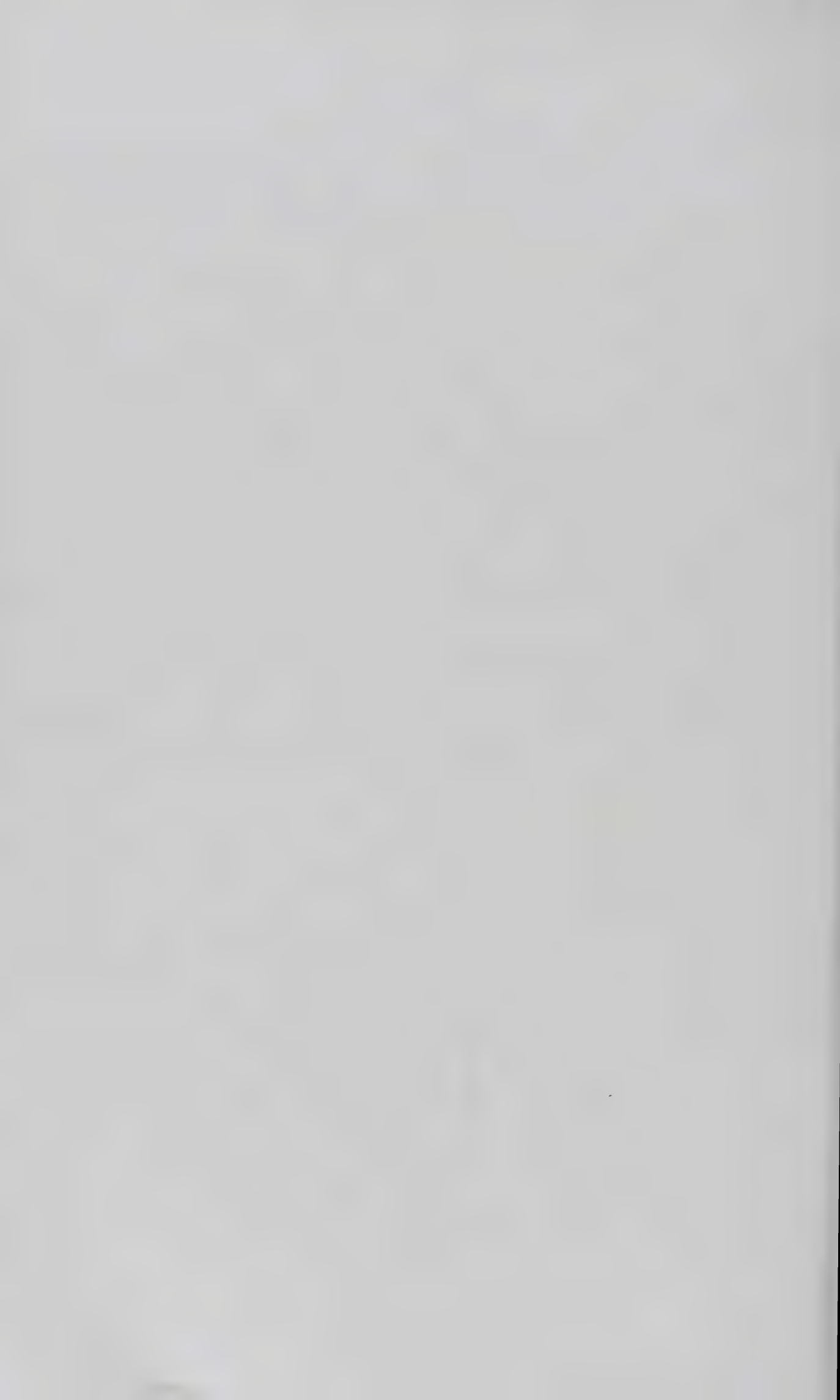
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Section I

CIRCULATORY SYSTEM  
(Normal Values in Cardiology)



## Chapter 1

### THE HEART

#### THE NORMAL HEART

APPLIED TO the heart, the term "normal" implies that this organ is structurally and functionally like that observed in healthy persons. An opinion regarding normality is frequently difficult to arrive at and can be made only after careful evaluation of the patient's history, physical examination and laboratory studies.

For example, two hearts may vary considerably in size and still be considered normal. However, if on successive examinations (in the absence of significant gain in weight), the heart is seen to become progressively larger, even though it may still be considered of normal size, this finding is significant. Similarly, the presence of heart murmurs which by themselves may appear to be of only slight significance must be considered important if they were previously absent. This applies also to alteration in the intensity of heart sounds, increase in blood pressure and other changes in the clinical status.

#### RHYTHM OF THE HEART

Although rhythm is usually regular in normal hearts, certain irregularities are known to occur in the absence of disease. *Sinus arrhythmia* consists usually of a change in the heart rate, which varies with the phases of respiration. In sino-auricular heart block there is observed either a sudden halving of the heart rate or long cycles interrupting the normal rhythm. *Sinus bradycardia* (slow heart rate) is observed normally in older persons and occasionally in young individuals with overactive vagal tone. The heart rate in such conditions may range from 40 to 60 beats per minute.

The occasional occurrence of premature contractions, whether auricular or ventricular, is said to be normal. It is difficult to give the exact range of the normal in terms of frequency of these ectopic beats. The appearance of one or two such beats per minute may be normal. The occurrence of numerous auricular or ventricular premature beats, however, is probably the result of some disturbance which cannot be considered normal. The same is true of coupled rhythm, auriculoventricular dissociation and nodal rhythm.

#### HEART SOUNDS

Normally, three sounds are heard over the precordium. The first sound is synchronous with cardiac systole. The second sound marks approximately the beginning of diastole. The third sound in a normal subject, when audible, is heard best at the apex in the recumbent position, halfway between the apex and the left sternal border. It occurs in diastole about one-tenth of a second after the second sound.

*The first sound is accentuated at the apex when the heart action is forceful—*for example, after exercise or excitement; it is diminished at the apex in the presence of obesity and emphysema. The first sound may be partially or entirely replaced by a murmur, or may be reduplicated in a normal heart.

The second sound is usually of greatest intensity at the base. Normally, the pulmonic second is slightly louder than the aortic second up to the age of twenty years. From the ages of twenty to thirty years the aortic second and pulmonic second are of about the same intensity. After the age of thirty years the aortic second is slightly louder than the pulmonic second. *The aortic second sound is accentuated normally after exercise or excitement.* Reduplication of the second sound may be normal or may be due to asynchronous closure of the two valves in the presence of disease.

The accentuation of the third sound or the appearance of an extra sound early in diastole may be caused by exercise, or it may be associated with a pathologic condition.

*The average duration of the first heart sound is 0.10 second, of the second heart sound, 0.08 second, and of the third heart sound, 0.04 second. The interval between the first and second sounds is about 0.25 second and between the second sound and the next first sound, 0.37 second. The third sound is heard in only a fraction of normal hearts.*

**QUALITY OF THE SOUNDS.** The normal heart sounds have a quality which can be represented by the sounds "*lub dup.*" The first heart sound is of lower pitch and longer duration than the second sound.

**EXTRACARDIAC SOUNDS.** Many sounds are produced outside the heart and must be distinguished from heart sounds. Some of these are produced in the pericardium, mediastinum and pleura. Sounds in the region of the apex have a short, musical quality and frequently appear to be close to the ear. The exact origin of these sounds is uncertain. Some writers have attributed an intracardiac origin to them; others believe them to be the result of friction of the heart against the thickened pericardium.

*A xiphisternal crunch may be regarded as a normal finding.* Crunching sounds normally heard in the tricuspid area are believed to be the result of friction of the heart against the pericardial sac.

A midsystolic click may be heard between the first and second heart sounds.

**MURMURS.** Murmurs should not always be considered an indication of cardiac abnormality. They are frequently observed in normal hearts. Many persons have a short, systolic murmur at the apex or in the pulmonic area after exercise and excitement. Similar murmurs frequently appear at these areas during pregnancy.

Cardiac murmurs have been divided according to their intensity into five grades. A Grade I murmur is just barely audible and is usually functional in origin. A Grade II heart murmur is of louder intensity and may be the result of functional or organic factors. Grade III, IV and V murmurs are usually due to organic disease. Systolic murmurs of Grade I and occasionally of Grade II intensity at the apex are generally the result of functional conditions which are

compatible with cardiac normality. Functional systolic murmurs are frequently heard in the pulmonic area.

### NORMAL HEART RATE

Direct palpation of the peripheral pulse furnishes a readily available and informative method that is still widely employed for determining cardiac rate. The blood vessel most often selected for examination of the pulse is the radial artery on the palmar surface of the wrist, where, as a rule, its superficial position renders it easily accessible. If for any reason the radial artery is not available, the pulse may be palpated at the temporal, facial, carotid or even the femoral arteries. Under certain conditions the peripheral pulse may not furnish an accurate record of the heart rate. This is true when the heart beat is so feeble that the pulse wave is not propagated into the peripheral vessels, or when certain irregularities in cardiac rhythm occur (auricular fibrillation, premature beats) in which a variable number of heart beats are too weak to reach the wrist. To avoid errors in estimating the heart rate, the peripheral pulse rate should be checked against that of the apex beat as determined by palpation.

The heart rate is subject to wide physiological variation, which must be considered in evaluating the significance of the heart rate at any given time. The heart rate may vary in normal persons as the result of age, sex, heredity, emotions, exercise, rest, changes of altitude and of external temperature, and during digestion. *The average heart rate of the normal human infant at birth is 130 beats per minute.* The rate does not become less than 100 until the third year of life. From then on it gradually decreases until adolescence is passed. *In the normal male adult at rest the heart rate averages 70 to 72 beats per minute. In women the rate is usually 8 to 10 beats higher per minute.* Heart rates of 60 or less are frequently observed in apparently normal members of the same family. Consistently elevated heart rates are also observed in normal persons, but appear to be less related to a familial trait.

Normally there is an increase in heart rate after exercise, nervous excitement, eating, application of external heat, and exposure to oxygen deficiency.

In view of the many conditions that may influence the heart rate in normal adults, it is evident that temporary changes in rate may have little pathological significance. On the other hand, a persistent increase in the heart rate to 100 or more beats per minute in a resting adult (if all emotional factors are excluded) is to be regarded as abnormal, and calls for careful investigation.

TABLE 1  
NORMAL PULSE AT VARIOUS AGES

Age	Beats per Minute
Fetus in utero . . . . .	140 to 150
Newborn infants . . . . .	130 to 150
1st year . . . . .	110 to 130
2nd year . . . . .	90 to 115
3rd year . . . . .	80 to 105
7th to 14th year . . . . .	75 to 90
14th to 21st year . . . . .	75 to 85
Over 21 years . . . . .	70 to 75

## CARDIAC OUTPUT

The output of blood by the heart per beat is spoken of as the systolic discharge or the stroke volume, and the output per minute as the minute volume. The minute volume is simply the product of the stroke volume and the heart rate. *The quantity of blood ejected at each beat of the left ventricle in the average healthy man during rest is from 60 to 70 ml. The minute volume of the heart under basal conditions varies in different persons from 3 to 4.6 liters. Grollman<sup>2</sup> found the value for a given person to be constant. The determinations made from time to time varied by no more than 2.5 per cent. He also showed that the basal cardiac output is a function of the surface area of the body. For normal persons the minute volume per square meter of body surface (termed the cardiac index) has an average value of 2.2 liters. The cardiac output is proportional to the basal metabolism and can be fairly adequately predicted for a normal person from the surface area. The average basal cardiac output per kilogram of body weight is 62 ml.*

The following physiological states vary or affect cardiac output:

1. **MUSCULAR EXERCISE.** In strenuous exercise the output increases from the basal level to from 19 to 37 liters per minute. The stroke volume increases to from 100 to 200 ml.

2. **HEAT.** No change in cardiac output occurs until the environmental temperature exceeds 30° C. Temperatures above this cause a moderate increase (5 to 30 per cent) in minute volume.

3. **DIGESTION.** Digestion of food produces an increase of 30 to 40 per cent above the basal level. This reaches its maximum about an hour after a meal, persists for about three hours, and then gradually declines. Ingestion of fluid also increases the cardiac output to a moderate degree.

4. **POSTURE.** The minute volume is somewhat greater in the recumbent position, and also with the subject standing quietly.

5. **EMOTIONS.** Excitement, anger and fear cause an increase of about 10 to 25 per cent.

6. **PREGNANCY.** In the later months the minute volume is increased to from 45 to 85 per cent above normal.

## CARDIAC FUNCTION TESTS

**ANOXEMIA TEST.** Several procedures have been devised to determine the functional capacity of the coronary circulation. Levy<sup>4</sup> has contributed considerably to the use of the anoxemia test, which, in essence, consists of the induction of oxygen insufficiency by having the patient breathe a mixture of 10 per cent oxygen and 90 per cent nitrogen. Under this condition coronary insufficiency produces characteristic electrocardiographic changes. The correlation of this test with the clinical diagnosis is good, but not invariable.

In normal subjects anoxemia lowers the amplitude of the T waves in all leads, and may even cause T wave reversal in leads II and III. The arithmetical sum of RS-T deviations in all four leads employed (I, II, III and IV) totals 3 mm. or more.

**EXERCISE TOLERANCE TESTS.** Numerous tests of exercise tolerance have been devised. They measure the efficiency of the heart, but do not eliminate other factors, chief among which are lack of physical training and nervousness, which may considerably influence the results of such tests.

In principle, the exercise tolerance tests consist in observation of the heart rate and blood pressure at rest, the performance of a fixed amount of physical activity and observations of the pulse and blood pressure at intervals after such work. The interpretation is based upon the height to which the heart rate and blood pressure rise, and the time necessary for them to return to the pre-exercise level.

The *Schneider Index* is an exercise tolerance test that has a rather complex method of scoring and is based upon the differences in heart rate and blood pressure measurement after change of body position and after exercise. A score above 9 is normal.

A newer test, devised by Johnson, Brouha and Darling,<sup>3</sup> and known as the *Fatigue Laboratory Index*, is especially applicable to athletes. In it the subject performs a standard exercise for five minutes or until he is exhausted, and the pulse is counted at intervals after the completion of the exercise. The score is calculated as follows:

Index of fitness for hard work =

$$\frac{\text{Duration of exhausting work in seconds} \times 100}{2 \times \text{sum of pulses from } 1-1\frac{1}{2}, 2-2\frac{1}{2} \text{ and } 4-4\frac{1}{2} \text{ minutes after the end of work}}$$

The score increases with the degree of physical fitness. A score of 100 is very good.

### CAROTID SINUS REFLEX

The carotid sinus is located in the expanded part of the common carotid artery, where it divides to form the internal and external carotid branches. Many observations have been made upon the depressor effects of the sinus.

In approximately 30 per cent of persons with normal cardiovascular systems, pressure upon the carotid sinus produces no alteration in the heart rate or the blood pressure. In the remaining 70 per cent cardiac slowing is less than six beats per minute and the decrease in the blood pressure is less than 10 mm. of mercury.

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## Chapter 2

# ELECTROCARDIOGRAM

### NORMAL ELECTROCARDIOGRAM IN THE THREE LIMB LEADS

WHILE ONE MAY speak of a normal electrocardiogram and associate that statement with a certain definite configuration of the complexes in the electrocardiogram, one should remember that, like the human face, no two electrocardiograms are identically alike. It is best, therefore, to think in terms of the "normal range" of the electrocardiogram, since there are many normal variations and deviations.

The normal electrocardiogram consists of two portions, an auricular complex (P wave) and a ventricular complex (QRS-T portion). The auricular complex or P wave consists of a round, blunt or pointed upward deflection 1 to 2 mm. in amplitude. The P wave represents the spread of the excitation wave from its origin in the sino-auricular node through the auricular muscle. It is sometimes followed by a dip called the auricular T wave, best seen in tracings of auriculoventricular heart block. *Normally, the P wave is smooth and upright.* There are many exceptions and variations, however, which will be discussed subsequently.

The P wave is followed by an isoelectric period, during which the string remains at rest except in the rare instances in which an auricular T wave is present. The period from the beginning of the P wave to the beginning of the QRS complex represents the time required for the impulse to spread from the sino-auricular node through the auricular muscle and through the auriculoventricular node and bundle of His to the point of its division into the right and left bundle branches in the upper part of the interventricular septum. A large part of this time is occupied by the passage of the impulse through the auriculoventricular node and bundle of His. *This interval, called the P-R interval, normally measures from 0.12 to 0.20 second in adults; from 0.12 to 0.16 second in children.*

The QRS complex is produced by the propagation of the cardiac impulse through the right and left bundle branches, their arborizations and the Purkinje fibers to the muscle of the ventricles. At the termination of the QRS complex the entire ventricular muscle has been involved by the excitation process. *The duration of the ventricular complex should range from 0.07 to 0.1 second.*

As with the P waves, the normal limits of variation of the QRS complex are wide. For instance, the absence of either the Q wave or the S wave, or both, is not abnormal. In a strictly normal QRS complex there is always present an R wave, which is more prominent than either the Q or S waves and is taller in lead II than in either leads I or III. It is to be remembered that slight degrees of axis deviation frequently develop in normal hearts and do not therefore, by

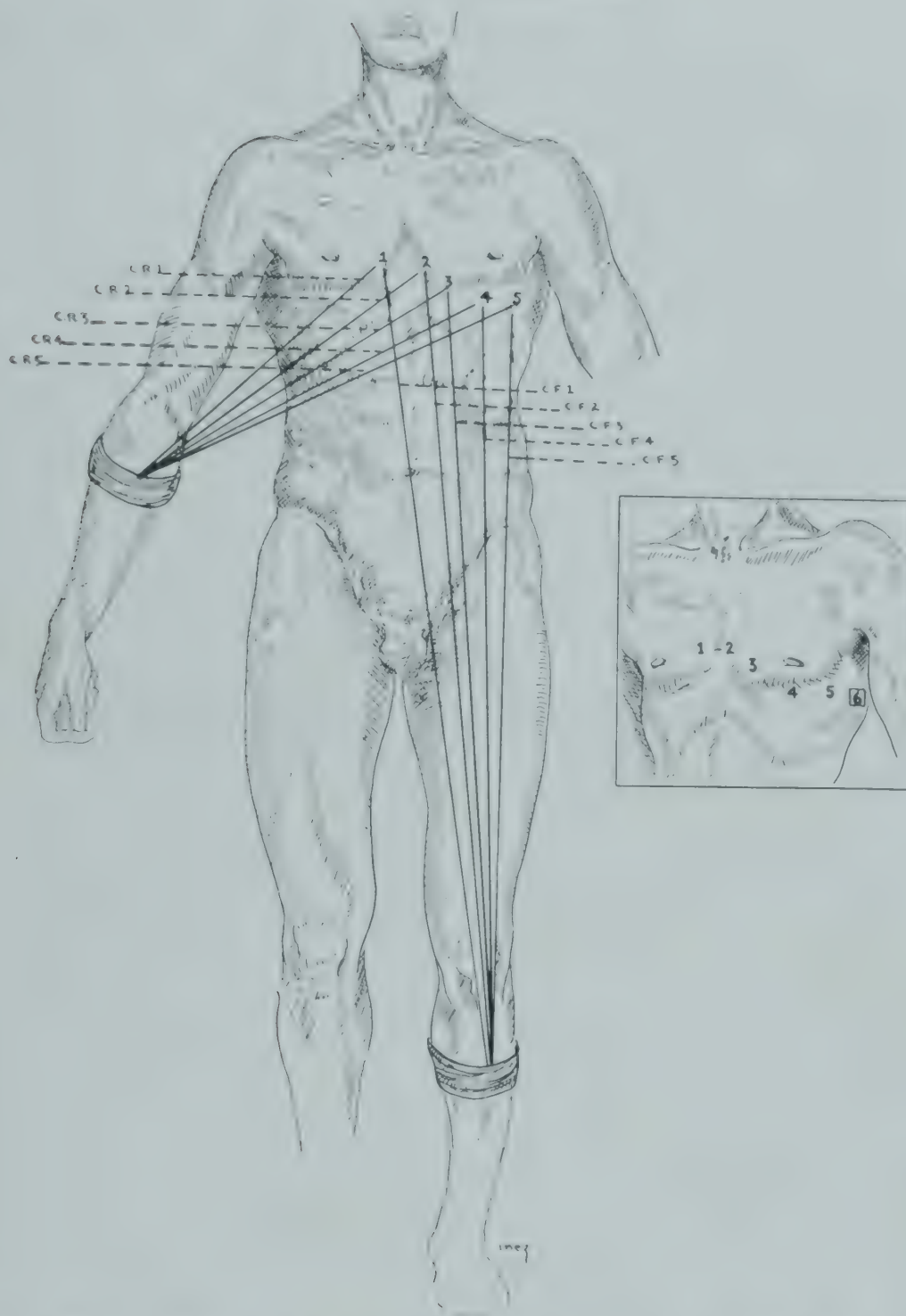


Fig. 1. Illustrating method of application of electrodes for chest leads. To take CF leads, the left leg electrode is placed in the precordial region in the different positions noted, the right arm electrode is placed on the left leg, and the electrocardiogram is taken on lead II. To take CR leads, the right arm electrode is placed on the right arm, the left arm electrode is placed on the precordium in the different positions noted, and the electrocardiogram is taken on lead I. *Insert.* Patient is turned in the left oblique position to illustrate application of axillary leads. (Stroud, W. D.: The Diagnosis and Treatment of Cardiovascular Disease, vol. 1, F. A. Davis Company.)

themselves, constitute evidence of disease. So too, in a strictly normal QRS complex the waves are clean-cut and unshaded. In certain instances, however, shading or even notching is seen in apparently healthy hearts.

The T wave is the terminal part of the ventricular complex and represents the retreat of the electrical activity in the ventricle as contrasted with the QRS complex, which represents the stage of invasion. It consists of a blunt, rounded, upward deflection rising gradually from the isoelectric line to a height

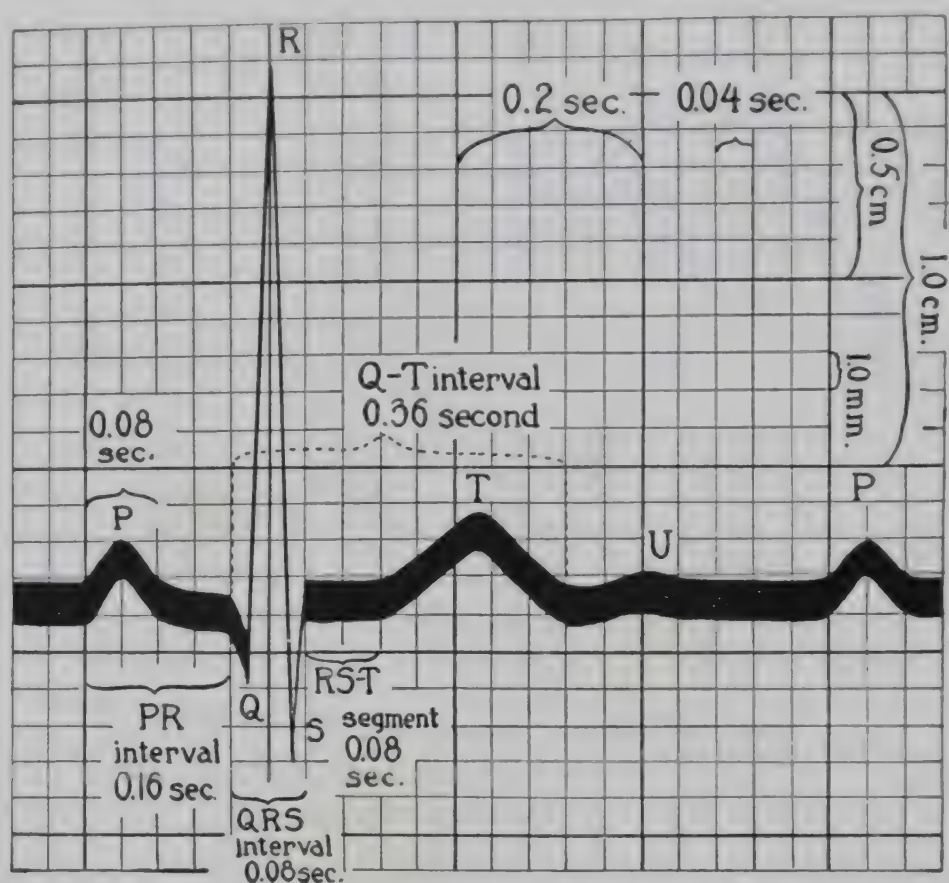


Fig. 2. Diagram of normal electrocardiogram, showing the individual complexes—P, QRS, T and U waves—their duration and amplitude, and the time intervals of significance—P-R interval, QRS duration and Q-T interval. The P-R interval represents the time required for the impulse to travel from the pacemaker in the sino-auricular node into and through the specialized ventricular conduction system, that is, the branches of the bundle of His. The QRS duration represents the initial activation of the ventricular myocardium set off by the impulse that has passed the end branches of the auriculoventricular conduction system. The interval from the beginning of Q to the end of T represents the duration of ventricular systole. The RST segment is an important part of the electrocardiogram, usually at an isoelectric level, and represents the electrical state of the heart during the height of systole. The amplitudes of the complexes as shown in the diagram are P wave, 0.1 millivolt; Q wave, 0.15 millivolt; R wave, 1.4 millivolt; S wave, 0.4 millivolt; T wave, 0.2 millivolt; U wave, 0.03 millivolt. To determine the amplitude of a wave (or complex) which is above the baseline we recommend measuring from the top of the baseline to the highest point of the wave; when the wave is below the baseline, measure from the bottom of the baseline to the lowest point of the wave. The time interval in this diagram is  $\frac{1}{25}$  second, and amplitude is expressed in  $\frac{1}{10}$  millivolt for each ordinate. (Modified from Ashman and Hull's "Essentials of Electrocardiography," Macmillan Company, from Graybiel and White: *Electrocardiography in Practice*.)

of 3 to 8 mm., and then sloping downward to the base line. The T wave is normally an upright wave. However, since it is frequently inverted in lead III in normal persons, this may not be an abnormality.

**RELATION OF VENTRICULAR COMPLEXES IN THE THREE INDIRECT LEADS.** Einthoven<sup>1</sup> showed that in the limb leads the waves in lead II represent an

algebraic summation of those in leads I and III. With upright complexes in all leads, the R waves and T waves are of greatest amplitude in lead II. In the presence of right and left axis deviation the amplitude of these complexes varies, depending on their relative positivity or negativity in leads I and III.

**THE Q-T INTERVAL.** The distance between the beginning of the Q wave and the end of the T wave represents electrical systole. It is believed that this interval is the best measurement we have for the duration of mechanical systole. While the Q-T interval (electrical systole) corresponds fairly closely with the value of mechanical systole as determined by heart sound records, this correspondence does not hold when the Q-T interval is abnormally shortened or lengthened. Mechanical systole is longer in the former and shorter in the latter. The Q-T length is a function of the heart rate, being shorter for the faster rates and longer for slower rates. Bazett<sup>3</sup> established the value for the normal Q-T interval, where  $\text{systole} = K\sqrt{\text{cycle}}$ , the constant K being 0.37 for men and 0.40 for women. Frediricia's<sup>5</sup> formula is  $S = 8.22\sqrt{c}$ , and Heglin and Holzmänn's<sup>6</sup> is  $S = 0.39\sqrt{c}$  for both men and women. The variation in the calculation of systole by these different methods is slight and for practical purposes may be disregarded.

## COMPARISON OF TIME RELATIONS OF THE ELECTROCARDIOGRAM WITH CERTAIN MECHANICAL EVENTS

**EXCITATION PROCESS.** The relation of the electrocardiogram to heart sounds is of both theoretical and practical import. The first heart sound begins in man from 0.009 to 0.039 second after the beginning of the QRS complex. The relation of the T to the second sound is variable; it may fall 0.03 second before or after the second sound.

The upstroke of P precedes the upstroke of the "a" wave in the human jugular curve by from 0.10 to 0.15 second. The upstroke of R precedes the upstroke of the "c" wave in the human jugular curve by from 0.10 to 0.15 second.

It therefore appears that the electrical events definitely precede the actual mechanical contraction of the heart. This type of observation forced early investigators to conclude that electrical currents that produce the waves of the electrocardiogram are not produced by the actual muscle contraction, but are the result of some process in the muscles that precedes and in some way prepares the muscle for contraction. This somewhat hypothetical process is referred to as the excitation wave or process. This view has never been entirely abandoned, but Einthoven<sup>1</sup> greatly reduced the time interval between the electrical and mechanical events by more refined instruments.

## EFFECT OF POSTURE

Changes in posture result in alterations, not only in the limb leads, but also in the precordial leads. These affect particularly the QRS complexes and the T waves. Occasionally they are quite marked and occur as frequently in normal as in diseased hearts. On standing, the QRS complexes become smaller

and the T waves notched, diphasic and occasionally inverted. Deep inspiration may change an inverted T2 to an upright configuration.

In the precordial leads the amplitude of the R and T waves is greatest in the supine and is decreased in the sitting position.

This emphasizes the importance of taking serial tracings with the patient in the same position. Alterations in the electrocardiogram may be attributed to myocardial change when they are, in reality, the result of nothing more than an alteration in the position of the heart.

### U WAVES

The U wave is an upward peak occurring after the T wave, often observed in normal tracings. It usually is considered to occur during ventricular diastole. Einthoven,<sup>4</sup> however, was of the opinion that this wave indicates persistent contraction in some fibers into early diastole. The U wave has an amplitude usually of 1.5 mm., begins 0.04 second after the end of the T and continues for 0.16 to 0.24 second, with an average duration of 0.20 second. No significance has been attached to the wave. Recently, however, Nahum and Hoff<sup>11</sup> have suggested that the U wave is part of the ventricular complex, is produced during systole and represents the supernormal period of recovery. This is a short period immediately after recovery from electrical excitation when the ventricle is most susceptible to ectopic beats. They believe that the majority of extrasystoles fall on the U wave or the part of the cycle where it occurs.

### PRECORDIAL LEADS

The pattern of the QRS complexes in the normal precordial leads depends upon the shape and size of the cardiac silhouette and, to a lesser degree, the site of the indifferent electrode.

Since the electrodes are placed on arbitrary points on the chest and because the part of the heart immediately beneath the electrode determines the potential differences of the exploring electrode, the configuration of the ventricular complexes may be expected to vary in different sizes and shapes of hearts and in different chest types. For example, in a ptotic heart the apex of the left ventricle may be situated between the C3 and C4 positions, whereas in a transversely placed heart the apex of the left ventricle may be in the C4 position or still farther to the left (see Figure 1).

The position of the indifferent electrode may modify the electrocardiogram in the precordial leads. We shall discuss the pattern of the CR leads in a patient of normal build. The leads commonly used are CR1, CR2, CR3, CR4 and CR5. In CR1 the amplitude of the QRS is small (4 to 6 mm.), the R wave is small (1 to 2 mm.), and the T wave is flattened and occasionally inverted. In CR2 the QRS complex is of normal amplitude, averaging 8 to 12 mm. The amplitude of R is about one-third the amplitude of S. In the CR3 position the amplitude of R increases slightly above that of CR2. In CR4 the R and S are of about equal amplitude. In CR5 and CR6 the amplitude of the R wave is greater than that of the S wave. The width of the QRS complex in the precordial leads may be slightly above that in the limb leads. The T waves are normally upright

from CR3 to CR4 positions. Diminished amplitude of the T wave may occur in transversely placed hearts. Slight deviation of the RS-T segments up to 2 mm. may occasionally be observed in normal hearts. These deviations may persist unchanged for long periods of time.

The supplementary report of the Committee of the American Heart Association on the Standardization of Precordial Leads has indicated certain relations between the size of the deflection in the three limb leads and those in the corresponding deflections in the precordial leads. The following numerical relations refer, in each case, to the values in millimeters of any synchronous points in the leads mentioned, such as is usually found in the peak of T:

$$\text{Lead IV}_F = \text{lead IV}_R + \text{lead II}$$

$$\text{Lead IV}_L = \text{lead IV}_F + \text{lead III}$$

$$\text{Lead IV}_T = \text{lead IV}_F + \frac{1}{3} (\text{lead II and lead III})$$

By means of these formulas it is possible to determine the deflection in lead IV if leads II and IV<sub>R</sub> have been obtained. Leads IV<sub>L</sub> and IV<sub>T</sub> can similarly be obtained, provided that synchronous points in the curve are considered.

### ESOPHAGEAL LEADS

The esophageal lead electrode consists of a thin wire insulated by insertion in a rubber tube, the tip of which is exposed. In the intact man this electrode is placed about as close to the heart as possible without surgical assistance. By

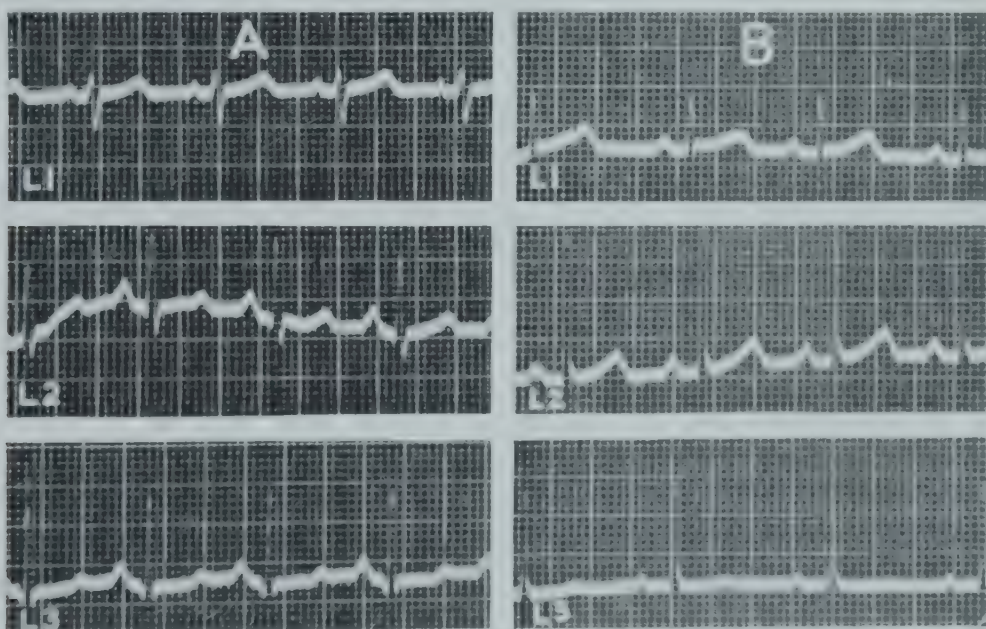


Fig. 3. Variations in normal electrocardiograms. A, Note the slight right axis deviation. This configuration is frequently seen in children and healthy young adults. B, Note the slight elevation of the S-T line in lead I and the shading of the QRS complex near the base line in lead II. Both these changes are seen in persons with normal hearts. (Stroud, W. D.: *The Diagnosis and Treatment of Cardiovascular Disease*, vol. 1, F. A. Davis Company.)

placing the tube at various levels in the esophagus one may record the potentials of the auricles or the posterior wall of the left ventricle. The exact position of the electrode may be confirmed by fluoroscopic examination.

The P waves of esophageal leads are usually peaked and of considerable amplitude. The configuration and amplitude of the P waves vary according to the position of the electrode relative to the auricles and ventricles.

### ELECTROCARDIOGRAM IN INFANCY AND CHILDHOOD

The electrocardiogram of the infant differs from that of the adult, since the heart mass is smaller, the ratio of heart weight to body weight is greater, and the position of the heart in the chest and torso is different.

The P wave in infancy and early childhood is shorter in duration than in the adult and sometimes is considerably taller so that it appears peaked in the

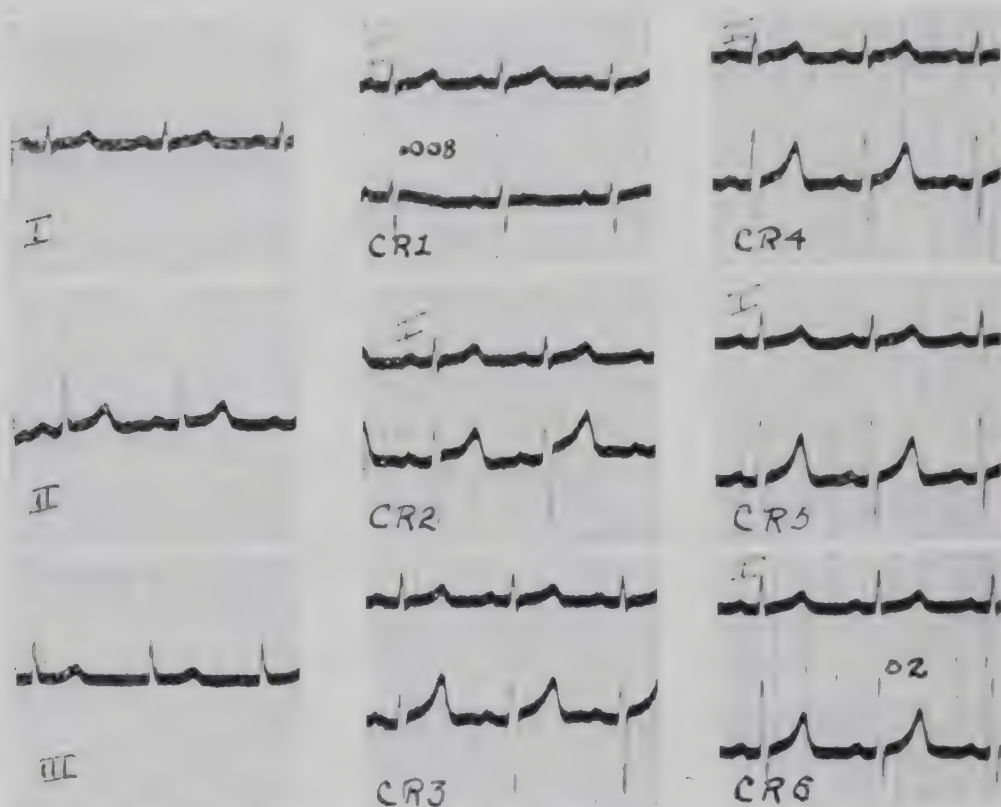


Fig. 4. Normal tracing with simultaneous registration of precordial leads, CR1 to CR6 with lead I. Note that the intrinsic deflection in CR6 is only slightly behind that of CR1. (Stroud, W. D.: *The Diagnosis and Treatment of Cardiovascular Disease*, vol. 1, F. A. Davis Company.)

limb leads. Often the P wave in a given lead varies in contour. The P-R interval varies in duration because of wandering of the pace-maker with sinus arrhythmia. This arrhythmia is common and, together with a rapid heart rate, is characteristic of the electrocardiogram of children and infants. At birth there is a tendency for the QRS complex to be small and inverted in lead I, the inversion persisting for two months or longer. The QRS complex remains fairly tall in all leads throughout childhood, and fairly prominent QRS waves may be encountered normally in the limb leads. Taller and more peaked T waves occur in infancy and childhood than in later adult life. Inverted T waves in CR2 are common in infants and children and may persist until adolescence. In infants and very young children the T wave may be inverted in CR3 and occasionally

in CR4. High phasic T waves are also normally common in these two leads in childhood.

The duration of the P wave and of the QRS complex and P-R interval is shorter in infants and children than in adults.

### ELECTROCARDIOGRAM AFTER MIDDLE AGE

No hard and fast rule can be laid down as to what may be called normal or abnormal in an older person. Some of the changes observed as compared to the average normal are as follows:

The T waves tend to be lower in amplitude; the QRS complexes are slightly wider; a left axis deviation is frequently observed; slurring of the QRS complexes at or near the base line in one or more leads is not necessarily abnormal in the older age groups; the T waves show some diminution of amplitude in limb and precordial leads.<sup>9</sup>

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## Chapter 3

# ROENTGEN CARDIAC MENSURATION

THE HEART, being a comparatively dense organ almost completely surrounded by air-containing viscera, is readily adaptable for roentgen study. Although its density is in most cases uniform, visualization of the contours in various positions permits individual chamber analysis.

## CARDIAC ROENTGEN ANATOMY

**POSTERO-ANTERIOR (PA OR FRONTAL) VIEW.** The *right border* presents two arches separated by a well-defined notch. Immediately above the diaphragm is the arch formed by the right atrium, and above this the second arch represents the border of the superior vena cava. In an older person this second arch is more likely to be caused by the ascending aorta. The straight line above this, adjacent to and parallel with the spine and merging with the arch of the superior vena cava, is the shadow formed by the innominate artery. Occasionally in the sthenic habitus, on deep inspiration, the inferior vena cava is visualized below the arch of the right atrium as a small triangular shadow in the cardiophrenic angle.

The *left border* presents three and occasionally four well-defined arcs. The lower arc, just above the diaphragm, is formed by the left ventricle, the middle arc by the pulmonary artery, and the upper arc by the aorta. Between the pulmonary artery and the left ventricle a fourth segment, the left auricular appendage, may sometimes be seen. Above the aorta, continuous with the cardiac silhouette and parallel with and adjacent to the spine, is the shadow cast by the left innominate vein or left subclavian artery, or both.

**RIGHT ANTERIOR OBLIQUE POSITION.** The chambers forming the cardiac contours vary with the degree of rotation. With the standard 40 to 50 degrees of rotation the chambers are as follows:

(a) *Diaphragmatic surface* (from posterior to anterior), by the inferior vena cava, right atrium and right ventricle.

(b) The *retrocardiac border* (borders on Holzkecht's space): from below upward, are the inferior vena cava, right atrium, and left atrium. The borders of the right and left atrium overlap in this view and cannot be differentiated in the normal. The supracardiac shadow is formed by the superior vena cava. Behind the heart is the descending aorta. In a 30 degree rotation this border from below upward consists of the right atrium and superior vena cava.

(c) The *anterior border* (from below upward) is formed by the right ventricle, pulmonary conus, artery and arch of the aorta. When the patient is rotated 30 degrees, this border from below upward consists of the left ventricle, pulmonary artery and the aorta.

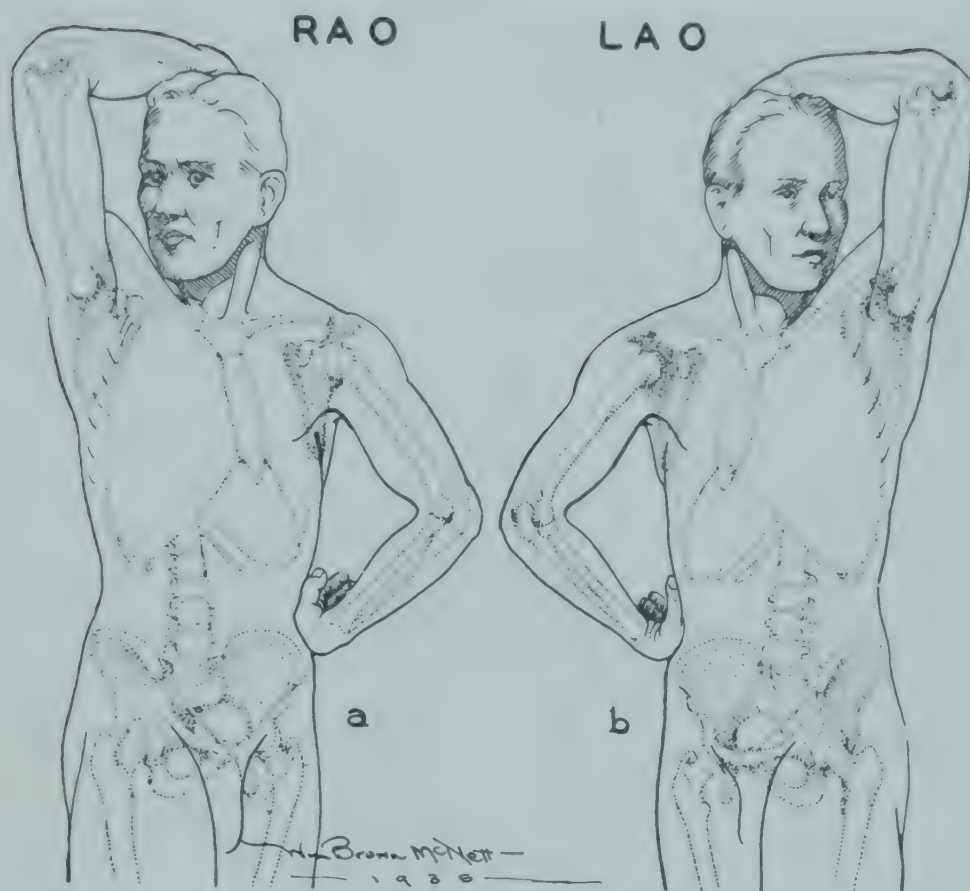


Fig. 5. Positions for anterior oblique views. Degree of rotation is to be determined for each individual by means of fluoroscopy. *a*, Right anterior oblique view; *b*, left anterior oblique view. Roesler, H.: Clinical Roentgenology of the Cardiovascular System, Charles C Thomas.

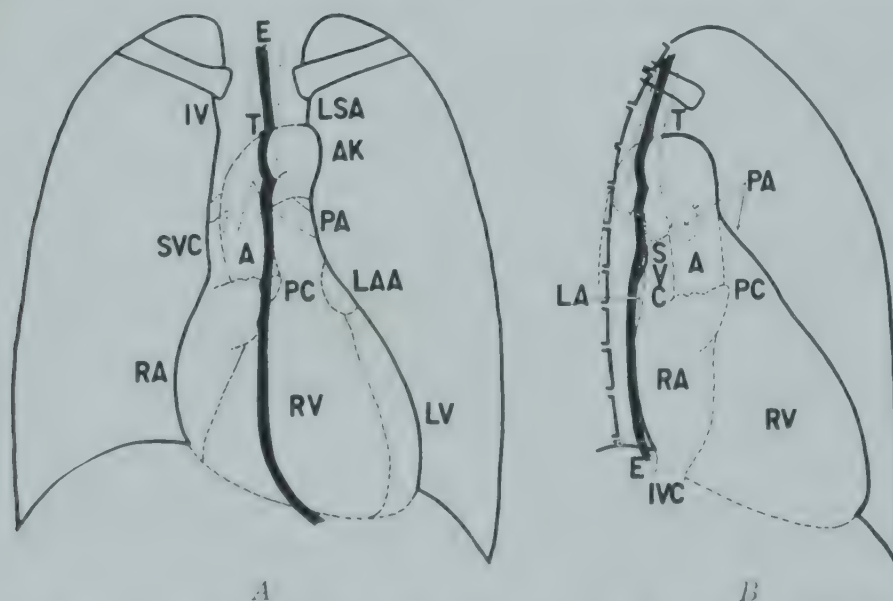


Fig. 6. *A*, Anteroposterior view; *B*, right oblique view (45 degrees). The broad irregular band marks the course of the esophagus; the heavy continuous lines indicate the visible contours of the heart and chest; the interrupted lines outline the invisible contours of the chambers, vessels, trachea and bronchi. *IV*, Right innominate vein; *SVC*, superior vena cava; *IVC*, inferior vena cava; *RA*, right auricle; *RV*, right ventricle; *PC*, pulmonic conus; *PA*, pulmonary artery; *LA*, left auricle; *LAA*, left auricular appendage; *LV*, left ventricle; *A*, aorta; *AK*, aortic knob; *LSA*, left subclavian artery and vein; *E*, esophagus; *T*, trachea. (Stroud, W. D.: The Diagnosis and Treatment of Cardiovascular Disease, vol. 1, F. A. Davis Company.)

LEFT ANTERIOR OBLIQUE POSITION. The chambers forming the cardiac contours when the degree of rotation is approximately 55 to 65 degrees are as follows:

- (a) The *diaphragmatic contour* is formed by the right ventricle.
- (b) The *anterior outline* is formed from below upward by the right ventricle, the right auricular appendix and the ascending aorta. The innominate artery forms the supracardiac shadow anterior to the trachea.
- (c) The *posterior silhouette* is formed from below upward by the left ventricle and left atrium.

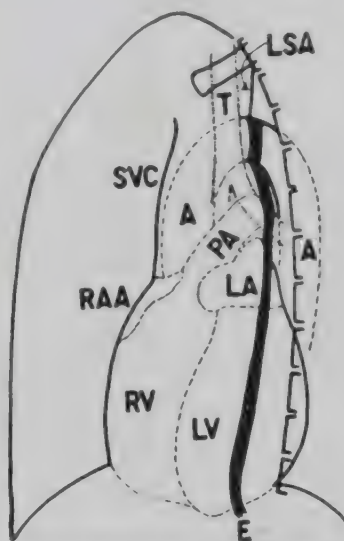


Fig. 7. Left oblique view. Stroud, W. D.: *The Diagnosis and Treatment of Cardiovascular Disease*, vol. 1, F. A. Davis Company.)

### MEASUREMENTS OF THE CARDIAC SHADOW

Roentgen measurement is the simplest method for determining heart size. It must be remembered that the normal is derived from the study of apparently normal persons and really represents an average. A range of variability exists, and the data obtained from an individual study are really compared with an average rather than absolute normal. Because of this, clinical data correlated with roentgen findings are of extreme importance. Furthermore, as Ungerleider<sup>10</sup> points out, mensuration is of greater value in evaluating cardiac enlargement as a whole, especially in those cases where the individual chambers are not distinctly involved. Mensuration is of no value in gross cardiac enlargement, except in serial comparative study.

**TRANSVERSE DIAMETER (TD).** The transverse diameter is the greatest width of the heart as seen in the postero-anterior view. It is the sum of the perpendiculars farthest to the left (ML) and right (MR) of the midline. The midline is obtained by drawing a perpendicular to a point on the sternum midway between the inner ends of the clavicle. *The average for adult men is 12.2 cm. (range, 9.3 to 14.5 cm.); women average 1.2 cm. less than men.*<sup>2</sup>

$$TD = MR + ML$$

By teleroentgenography the transverse diameter can be compared with prediction charts based upon height and weight. Age and sex have been elimi-

nated as inconsequential, since their influence is small as compared to height and weight. At present, according to Sherman,<sup>5</sup> the most satisfactory simple prediction charts are those of Ungerleider and Gubner.<sup>12</sup>

TABLE 2

## A STUDY OF 1460 TELEROENTGENOGRAMS

INCLUDES ONLY CASES IN WHICH THE SYSTOLIC BLOOD PRESSURE RANGED BETWEEN 110 AND 145 MM. OF HG AND THE DIASTOLIC BETWEEN 60 AND 100 MM. OF HG

(Ungerleider and Clark, 1939)<sup>11</sup>

<i>Index</i> <i>W</i> × 10	<i>H</i>	<i>Cases</i>	<i>Average</i> <i>T.D.</i> <i>Heart</i> ( <i>Cm.</i> )
15.....	15.....	1	10.4
16.....	16.....	4	10.8
17.....	17.....	12	11.0
18.....	18.....	32	11.7
19.....	19.....	61	11.8
20.....	20.....	88	12.3
21.....	21.....	118	12.3
22.....	22.....	179	12.8
23.....	23.....	188	13.1
24.....	24.....	198	13.3
25.....	25.....	142	13.7
26.....	26.....	159	14.0
27.....	27.....	97	14.0
28.....	28.....	75	14.2
29.....	29.....	38	14.5
30.....	30.....	28	14.7
31.....	31.....	24	15.1
32.....	32.....	6	14.9
33.....	33.....	7	15.0
34.....	34.....	1	13.8
35.....	35.....	2	14.4
Total 1,460			(Average for all cases, 13.277 cm.)

**LONGITUDINAL DIAMETER.** The long or oblique diameter is obtained by drawing a line from the juncture of the right atrium and superior vena cava (on the right side in the postero-anterior view) to the radiologic apex of the heart (juncture of the left cardiac contour with the diaphragm). *The average length for adults is 13.6 cm., with a maximum of 15.5 cm. and a minimum of 11 cm.*<sup>6</sup>

The broad diameter is the sum of two perpendiculars drawn from the long diameter. The perpendicular on the left extends from the juncture of the pulmonary artery conus segment with the left ventricle (postero-anterior view). The perpendicular on the right extends from the right cardiophrenic angle (juncture of the right atrium with the diaphragm). The range for adult males is 8 to 11.2 cm., *average 9.8 cm.*<sup>5</sup>

**LEFT VENTRICULAR DIAMETER.** The left ventricular cord (LV) subtends the arc of the left lower cardiac and represents the left ventricular cord in the postero-anterior view (apex of the heart to the point of opposite pulsation).

*The average adult male size is 9.6 cm. (range, 6.6 to 12.5 cm.); the average adult female size is 8.5 cm. (range, 6.0 to 10.5 cm.).*<sup>5</sup>

**LEFT VENTRICULAR WALL THICKNESS.** A line drawn from the outermost part of the left cardiac contour perpendicular to the left cord represents the thickness of the left ventricular wall.<sup>7</sup> *The average thickness is 1.3 cm. (range, 0.6 to 2.0 cm.).*

The right ventricular cord (RV) connects the right cardiophrenic angle and the radiologic apex of the heart, which is the right ventricular diameter. *The average is 11.6 cm. (range, 8.5 to 14.7 cm.).*

**RIGHT AURICULAR DIAMETER.** The right auricular diameter is measured by a line drawn from the intersection of the right auricle and the great vessels on the right side to the intersection of the lower right border of the heart and inferior vena cava. *The average is 5.0 cm. (range, 3.5 to 7.5 cm.).*

**LEFT AURICULAR DIAMETER.** A line drawn from the midline to the point of opposite pulsation on the left cardiac contour is used as an indication of the left auricular diameter. *This averages 4.2 cm., with a range of 3.5 to 5.0 cm.*

The horizontal depth diameter (TD hor.) is the line drawn on lateral chest films from the most distal dorsal point horizontally to the inner chest wall. *The average male adult measures 9.4 cm. (range, 7.6 to 10.9 cm.), and the average female adult 8.3 cm. (range, 7.0 to 10.5 cm.).*<sup>6</sup>

The lateral diagonal diameter (TD-br) measures the length of two perpendiculars drawn from the farthest ventral and dorsal points on the cardiac contour in the lateral view to a line drawn from the bifurcation of the trachea to the sternodiaphragmatic angle. *The average for adult males is 9.3 cm. (range, 7.1 to 11.5 cm.).*<sup>6</sup>

### CARDIAC SURFACE AREA

The diaphragmatic surface and the base of the heart are not visualized on film, and these curves must be constructed artificially. The surface area may be computed by use of the planimeter or by counting the number of millimeters enclosed by the heart area.<sup>7</sup> The computed surface area is then compared with prediction formulas. Since this frontal area of the heart is an ellipse, the area is

$$A = \frac{\pi}{4} L \times B$$

where L = long diameter and B = broad diameter (see Fig. 8). *The average area for adult males, standing position, is 102 cm.<sup>2</sup> (range, 75 cm.<sup>2</sup> to 130 cm.<sup>2</sup>), and for adult females, 90 cm.<sup>2</sup> (range, 60 to 110 cm.<sup>2</sup>). It is 20 per cent greater in the recumbent position.*<sup>6</sup>

**ESTIMATION OF HEART AREA. HODGES AND EYSTER'S METHOD.** The predicted heart area in square centimeters is equal to the measurement of age in years, multiplied by the factor 0.0204, plus the measurement of stature in centimeters multiplied by the factor 0.8668, plus the measurement in kilograms multiplied by the factor 0.337, minus the constant 63.8049.

**NEWCOMER'S METHOD.** The cardiac rectangle (broad times the long diameter of the heart) is compared with the rectangle of the lung fields. The pul-

monary rectangle is obtained by drawing a line through the upper border of the left half of the diaphragm, a second longitudinal line tangent to the apices, and a line through the spinous process intersecting these lines (medium diameter). The area equals length times width (film in full inspiration).

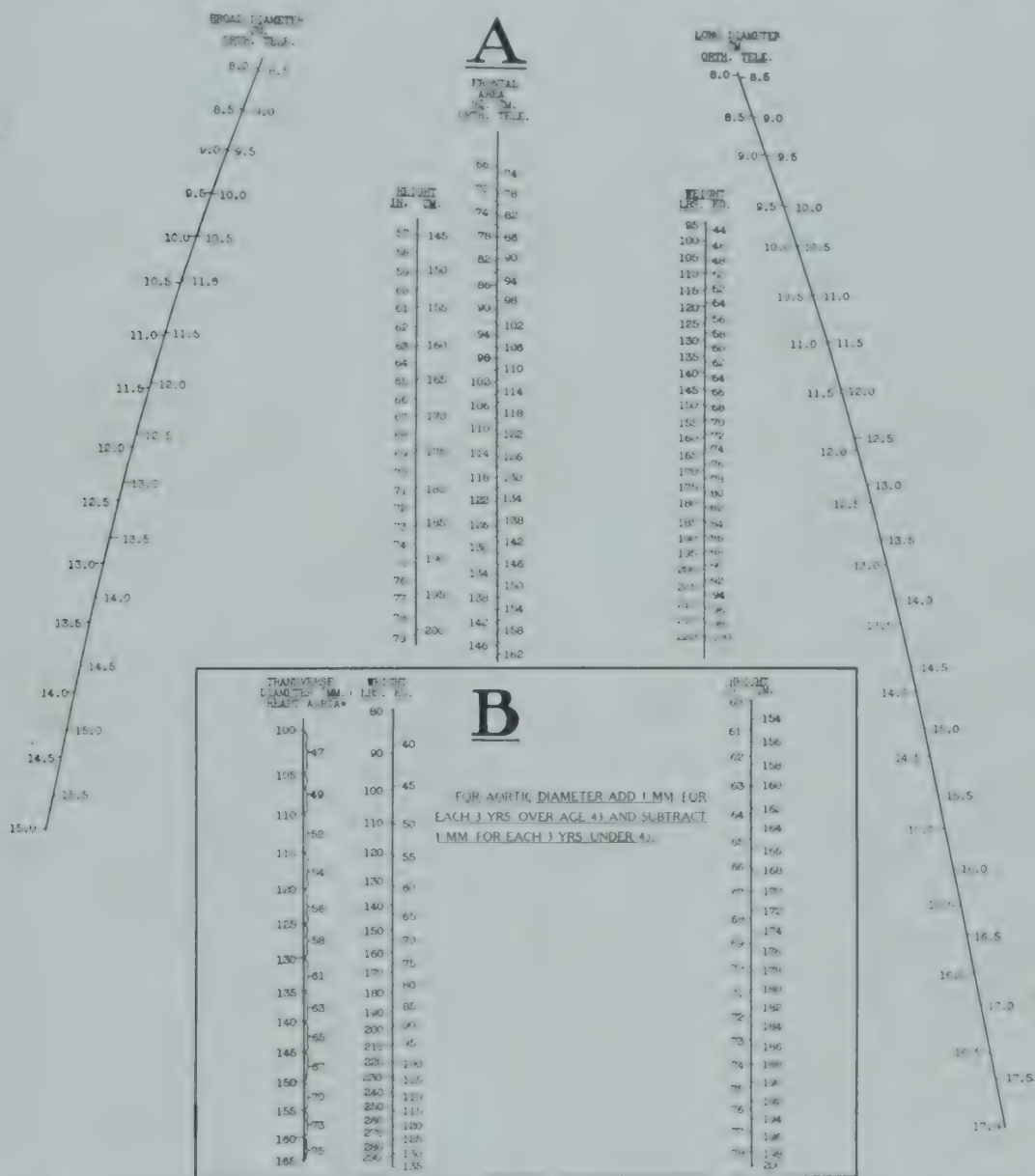


Fig. 8. Nomograms for area and transverse diameter of frontal heart silhouette. A, Predicted area from weight and height, and actual area from long and broad diameters, for orthodiagram and teleroentgenogram. B, Transverse diameter and aortic silhouette predicted from weight and height, for teleroentgenogram. The values for actual (or predicted) area are read at the point at which a straight line extending from the long and broad diameters (or weight and height) intersects the cardiac area scale. Orthodiagram values are on the left, teleroentgenogram values on the right. In B the predicted transverse diameter (left side of scale) or aortic arch (right side of scale) is obtained as an extension of a straight line connecting height and weight. A correction for age is necessary for the aortic diameter. (Ungerleider, H. E.: Radiology, vol. 48.)

Hearts are then classified as asthenic, medium and sthenic. The average of asthenic types is 20 per cent; of medium types, 22 per cent; of sthenic types, 26 per cent; of all types, 23 per cent.

TABLE 3  
PREDICTION FOR NORMAL CARDIAC AREA AND TRANSVERSE DIAMETER  
(Hodges and Eyster, 1926)<sup>2</sup>

Stature		Area (Sq. Cm.)	Transverse Diameter (Mm.)	Weight		Area (Sq. Cm.)	Transverse Diameter (Mm.)
Cm.	In.			Kg.	Pounds		
150	59	66.71	66.74	50	110	17.00	40.90
151		67.57	66.55	51	112.2	17.34	41.71
152	60	68.44	66.36	52	114.4	17.68	42.53
153		69.31	66.16	53	116.6	18.02	43.35
154		70.18	65.97	54	118.8	18.36	44.17
155	61	71.05	65.77	55	121	18.70	44.98
156		71.97	65.58	56	123.2	19.04	45.80
157		72.79	65.39	57	125.4	19.38	46.62
158	62	73.66	65.19	58	127.6	19.72	47.44
159		74.53	65.00	59	129.8	20.06	48.26
160	63	75.40	64.80	60	132	20.40	49.07
161		76.27	64.61	61	134.2	20.74	49.89
162		77.14	64.42	62	136.4	21.08	50.71
163	64	78.01	64.22	63	138.6	21.42	51.53
164		78.88	64.03	64	140.8	21.76	52.35
165	65	79.75	63.83	65	143	22.10	53.16
166		80.62	63.64	66	145.2	22.44	53.98
167		81.49	63.45	67	147.4	22.78	54.80
168	66	82.36	63.25	68	149.6	23.12	55.62
169		83.23	63.06	69	151.8	23.46	56.44
170	67	84.10	62.86	70	154	23.80	57.25
171		84.97	62.67	71	156.2	24.14	58.07
172		85.84	62.47	72	158.4	24.48	58.89
173	68	86.71	62.28	73	160.6	24.82	59.71
174		87.58	62.09	74	162.8	25.16	60.52
175	69	88.45	61.89	75	165	25.50	61.34
176		89.32	61.70	76	167.2	25.84	62.16
177		90.19	61.50	77	169.4	26.18	62.98
178	70	91.06	61.31	78	171.6	26.52	63.80
179		91.98	61.12	79	173.8	26.86	64.61
180	71	92.80	60.92	80	176	27.20	65.43
181		93.67	60.73	81	178.2	27.54	66.25
182		94.54	60.53	82	180.4	27.88	67.07
183	72	95.41	60.34	83	182.6	28.22	67.89
184		96.28	60.15	84	184.8	28.56	68.70
185	73	97.15	59.95	85	187	28.90	69.52
186		98.02	59.76	86	189.2	29.24	70.34
187		98.89	59.56	87	191.4	29.58	71.16
188	74	99.76	59.37	88	193.6	29.92	71.98
189		100.63	59.18	89	195.8	30.26	72.79
190		101.50	58.98	90	198	30.60	73.61
191	75	102.37	58.79	91	200.2	30.94	74.43
192		103.24	58.59	92	202.4	31.28	75.25
193	76	104.11	58.40	93	204.6	31.62	76.06
194		104.98	58.21	94	206.8	31.96	76.88
195		105.85	58.01	95	209	32.30	77.70
196	77	106.72	57.82	96	211.2	32.64	78.52
197		107.59	57.62	97	213.4	32.98	79.34
198	78	108.46	57.43	98	215.6	33.32	80.15
199		109.39	57.23	99	217.8	33.66	80.97
200	79	110.20	57.04	100	220	34.00	81.79

To find normal transverse diameter for a given individual, add T-D figure for stature to T-D figure for weight and to this total add 1 mm. for every decade of age; e.g., height, 6 feet; weight, 187 pounds; age, 50 = 134.86 mm. T-D or 60.34 + 69.52 + 5.

$$\text{Predicted T-D} = 0.1094 \times A = 0.1941 \times H + 0.8179 \times W + 93.8623$$

**AORTIC MEASUREMENT.** In the postero-anterior roentgenogram it is possible to measure the aortic knob. The esophagus is filled with barium, and a horizontal line is drawn from the deepest esophageal impression to the point farthest to the left of the aortic knob (2 mm. are subtracted for the thickness of the esophageal wall). The measurements are compared with a prediction chart.

**PULMONARY VESSELS.** The secondary branches of the right pulmonary artery can be measured in the teleroentgenogram. The part perpendicular to the right main bronchus measures 10 to 14 mm. Tertiary branches measured on end should be less than 0.5 cm.

The left pulmonary artery can be measured just as it clears the heart when the patient is in a 5 degree left anterior oblique position. *Normally this measures between 20 and 30 mm. (average, 25 mm.).*

### VOLUMETRIC RECONSTRUCTION

Serial roentgenograms are made every 15 degrees of rotation, rotating the patient through 360 degrees. The patient is replaced by modelling material and

TABLE 4

DIMENSIONS OF THE CARDIAC SILHOUETTE AND THE THORACO-ABDOMINAL CAVITY IN NORMAL INFANTS BY CERTAIN SUBDIVISIONS OF AGE UNDER 1 YEAR

(Bakwin and Bakwin, 1935)<sup>1</sup>

Age, Mos.	Area of Heart, Sq.Cm. (S.D.* 4.5)	Trans- verse Diam- eter of Heart, Mm. (S.D., 6)	Long Diam- eter of Heart, Mm. (S.D., 7.5)	Heart Angle De- grees (S.D., 6)	Diam- eter of Medi- asti- num, Mm. (S.D., 6.2)	Area of Tho- racic Cavity Sq. Cm. (S.D., 12.5)	Length of Thorax Mm. (S.D., 8)	Width of Thorax Mm. (S.D., 8)	Area of Abdom- inal Cavity Sq.Cm. (S.D., 17.5)	Length of Ab- domen, Mm. (S.D., 11.5)	Width of Ab- domen, Mm. (S.D., 7.5)
Birth	14	49	54	32	26	40	51	90	94	106	99
1	18	54	59	33	29	43	55	95	102	110	107
2	21	58	63	33	31	48	60	101	109	115	113
3	23	61	67	33	32	55	64	106	118	118	118
4	26	64	70	34	32	61	67	111	124	122	122
5	28	66	73	34	33	67	71	116	132	124	127
6	30	68	75	34	33	73	74	121	140	127	131
7	31	70	77	35	33	78	76	125	147	129	134
8	33	72	79	35	33	82	79	129	155	132	138
9	34	73	80	36	32	85	81	131	159	135	140
10	35	74	81	36	32	88	83	133	163	137	142
11	35	74	81	37	32	90	84	135	166	138	144
12	36	75	82	38	32	92	85	137	169	140	144

\* S.D. means standard deviation.

the process reversed, molding the plastic into the size and shape of the original heart. The amount of water replaced by the model gives the volume of the heart, which, multiplied by the average density, gives the weight.

**CARDIOTHORACIC RATIO.** The cardi thoracic ratio is the comparison of the greatest transverse diameter of the heart (TD) with the greatest internal diam-

eter of the thoracic cage (ID). It is based on the assumption that the transverse diameter should be less than one-half the internal diameter (47 per cent). This ratio is crude and inaccurate, since ordinarily the heart may be considerably less than one-half the thoracic cage, and appreciable enlargement may escape detection if this is used as an index of normal heart size.

TABLE 5  
CARDIOTHORACIC RATIO IN INFANTS BY CERTAIN SUBDIVISIONS OF AGE UNDER 1 YEAR  
(Bakwin and Bakwin, 1935)<sup>1</sup>

Age Range Weeks	Normal Infants			Undernourished Infants		
	No. of Cases	Mean (Mm.)	Standard Deviation (Mm.)	No. of Cases	Mean (Mm.)	Standard Deviation (Mm.)
0 to 3.....	52	55.31	4.94	..	.....	
4 to 7.....	36	57.61	6.02	38	53.42	4.70
8 to 15.....	71	56.75	5.67	70	54.32	5.10
16 to 23.....	42	56.67	5.56	42	53.76	5.48
24 to 31.....	27	55.81	5.53	28	52.64	5.08
32 to 39.....	35	55.97	4.95	21	53.95	4.77
40 to 47.....	19	54.37	5.24	10	52.89	5.66
48 to 55.....	22	52.64	4.31	20	52.80	3.40

ROENTGEN CRITERIA FOR INDIVIDUAL CHAMBER ANALYSIS

LEFT VENTRICLE. Normally the ratio of the outflow tract to inflow tract is 5:4.

OUTFLOW TRACT ANALYSIS. Outflow tract enlargement is manifested by an increase in the length of the left ventricular cord. Normally, this segment ends above the diaphragm. The outflow tract may also increase by rounding. Normally, the arc of the left ventricle, if extended, will fall beyond the confines of the film or fluoroscopic screen. When enlargement occurs it falls within these confines.<sup>7</sup>

INFLOW TRACT ANALYSIS. This is best visualized in the left anterior oblique position. Enlargement is manifested by an increase in the convexity of contour and encroachment on the retrocardiac space. Displacement of the interventricular groove is downward and forward.

RIGHT VENTRICLE. The normal ratio of inflow to outflow tract is 5 or 6:4.<sup>7</sup>

The right ventricle does not contribute to the cardiac contour in the postero-anterior view. Outflow tract enlargement causes a straightening of the upper left contour between the aortic arc and the left ventricular segment. In the right anterior oblique position the upper anterior part of the cardiac contour normally manifests itself by a concavity. When the outflow tract of the right ventricle enlarges, the infundibulum bulges forward and causes straightening or convexity of this segment of the cardiac silhouette.

In the left anterior oblique position the diaphragmatic part of the heart

is formed by the right ventricle. Normally this is about four fingers' breadth. When the inflow tract enlarges, the posterior diaphragmatic surface of the heart is increased, displacing the left ventricle posteriorly and upward. The anterior arc is also elongated.

TABLE 6

INTERNAL DIAMETER OF THE CHEST BY AGE AND SEX AND PERCENTAGE RELATIONSHIP OF TRANSVERSE DIAMETER OF THE HEART TO THE INTERNAL DIAMETER OF THE CHEST (Lincoln and Spillman, 1918)<sup>3</sup>

Boys					
Age	Number of Cases	Internal Diameter	± Standard Deviations	Percentage Relation of Heart to Internal Diameter	± Standard Deviations
2.....	7	15.5	0.9	49	2.0
3.....	11	17.2	0.6	47	3.5
4.....	23	17.7	0.9	48	2.5
5.....	38	18.6	1.0	48	3.4
6.....	35	19.5	1.2	47	3.9
7.....	35	19.7	1.3	46	3.0
8.....	31	20.5	1.0	46	3.5
9.....	33	21.1	1.2	45	3.6
10.....	21	21.5	1.3	46	3.3
11.....	19	22.0	1.1	46	2.7
12.....	15	23.1	1.6	43	2.7
13.....	9	23.6	1.2	52	8.0

Girls					
2.....	5	16.4	0.5	45	2.0
3.....	7	16.7	1.2	47	3.2
4.....	24	17.6	0.8	49	2.5
5.....	36	17.9	0.9	48	2.7
6.....	32	18.4	1.2	48	3.3
7.....	35	19.3	1.1	47	3.1
8.....	30	20.0	1.2	47	3.2
9.....	27	20.6	1.2	46	2.7
10.....	19	20.9	1.2	46	2.9
11.....	23	22.0	1.4	45	4.3
12.....	20	22.9	1.3	45	4.3
13.....	8	23.4	1.5	46	4.0

LEFT ATRIUM. The left atrium only occasionally contributes to the cardiac silhouette in the postero-anterior view. Left auricular enlargement is manifested by elevation and compression of the left main bronchus; by obliteration of the infrabronchial space in the left anterior oblique position or encroachments on the esophagus as seen in the right anterior oblique position. This is valid only when the esophagus is in the midline when viewed in the postero-anterior projection.

RIGHT AURICLE. In the left anterior oblique position the right auricular

curve is lengthened, and in the right anterior oblique position there is obliteration of the retrocardiac space without esophageal displacement.

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## Chapter 4

### CIRCULATION TIME

THE MEASUREMENT of the velocity of blood flow, or circulation time, requires the introduction of a foreign substance into the blood stream at one point and the subjective or objective perception of the time of its arrival at another point. By the use of various foreign substances (radium C, fluorescein, decholin, amyl nitrate, alpha-lobeline, papaverine, saccharin, carbon dioxide, calcium gluconate) the circulation time from arm to heart, arm to face, arm to tongue, arm to arm and arm to carotid, and the pulmonary circulation time have been determined.

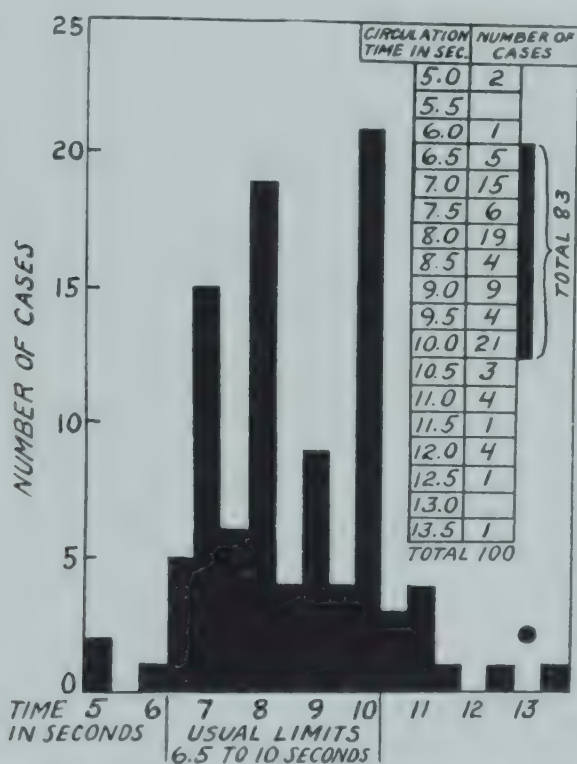


Fig. 9. Circulation time in normal children from 8 to 16 years of age. Saccharin method used with arm-to-tongue readings. (Averbuck, S. W., and Friedman, W. F.: *Am. J. Dis. Child.*, vol. 49.)

Koch<sup>10</sup> determined the circulation time by injecting fluorescein into the antecubital vein and noting its time of arrival at the lips by using a Wood light. Blumgart and Weiss<sup>5</sup> injected radium C into the antecubital vein and noted its time of arrival at various parts of the body by a Wilson cloud chamber. More recently the circulation time of blood has been determined by using radio-sodium (i.e., a labelled solution of sodium chloride) as a tracer.<sup>11a</sup> These methods are objective determinations that eliminate the human element.

The subjective methods depend upon the patient's ability to signify the

CIRCULATORY SYSTEM

TABLE 7  
CIRCULATION TIME

<i>Method</i>	<i>Number of Normal Subjects</i>	<i>Distance Measured</i>	<i>Range (Seconds)</i>	<i>Investigator</i>
Alpha-lobeline	39	Arm to respiratory center	4 9-16 5	Lilienfeld and Berliner (1942)
Amyl nitrate	100	Lung to face	14-25	Gross (1945)
Calcium gluconate	60	Arm to throat	10-16	Goldberg (1936) Spier, Wright and Saylor (1936) Baer and Slipakoff (1938)
	40	Arm to tongue	7-22	
	40	Arm to perineum	12-32	
	40	Arm to left foot	10-46	
	21	Arm to tongue	9-16	
Carbon dioxide	30	Lung to respiratory center	5-10	Gubner, Schnur and Crawford (1939)
Decholin	60	Arm to tongue	10-16	Tar, Oppenheimer and Sager (1933)
Ether	21	Arm to lung	4- 8	Baer and Slipakoff (1938) Webb, Sheinfeld and Colin (1936) Hitzig (1935)
	70	Arm to lung	4- 8	
	164	Arm to lung	3- 8	
Fluorescein	212	Arm to lip	15-20	Lange and Boyd (1943) Fishback, Guttman and Abramson (1942)
	50	Arm to eye	7-15.6	
Magnesium sulfate	92	Arm to throat	7.0-17.8	Bernstein and Simkins (1939)
Papaverine	50	Arm to respiratory center	15.4-27.0	Elek and Solarz (1942)
Radium C	62	Arm to right auricle	2-14	Blumgart and Weiss (1927)
	62	Pulmonary circulation	5-17	
	53	Arm to arm	14-24	
Saccharin	21	Arm to tongue	9-16	Baer and Slipakoff (1938) Fishberg, Hitzig and King (1933)
	100	Arm to tongue	9-16	
Rudiosodium	11	Arm to foot	15-105 Av., 39	Hevesy (1948)

exact arrival time of various substances by means of certain signals or spoken words. The calcium gluconate,<sup>2, 9, 16</sup> decholin,<sup>12</sup> magnesium sulfate<sup>1</sup> and saccharin<sup>3, 8, 18</sup> methods depend upon the patient's signifying the perception of a specific taste after the injection of these substances into the antecubital vein.

The ether method<sup>2, 12, 18</sup> consists in injecting a small amount of ether into an antecubital vein and measuring the time elapsing after the injection until it is detected on the subject's breath.

Alpha-lobeline,<sup>3, 15</sup> carbon dioxide<sup>11</sup> and papaverine<sup>6</sup> are respiratory stimulants, and the circulation time is determined by noting increases in both depth and rate of respiration after introduction of these substances, either by way of the lungs or intravenously.

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## Chapter 5

### BLOOD PRESSURE

THE PRIMARY function of the circulation may be considered to be the maintenance of normal capillary blood flow, which is essential for tissue metabolism. This can be accomplished by a normal peripheral resistance with normal arterial pressure, or an increased peripheral resistance with an elevated arterial pressure. Arterial pressure depends mainly on peripheral resistance and cardiac output and varies through a range rather than remains fixed at a definite point. Since certain pathologic states either cause or result in an increase in peripheral resistance, they tend to be associated with an elevated arterial pressure. This change begins gradually, and may fail to progress further after reaching a certain point. Thus persons developing arterial hypertension will, for a time at least, have a blood pressure range overlapping at its lower levels with the upper levels of a normal range. Once the condition has progressed to a certain stage, this confusion does not occur, but is present until the lowermost limit of the hypertensive range is above the uppermost limit of normal blood pressure.

#### ARTERIAL PRESSURE

1. DIRECT METHOD. This consists in introducing directly into an artery a needle connected with a manometer or recording system. This measures pressure under conditions of flow, which is slightly lower than the pressure required to occlude the artery. Moreover, if the needle is connected with a manometer with a large inertia, such as the mercury manometer frequently used in animal experimentation, pulsation will be minimal and the instrument will record, not systolic or diastolic pressure, but mean pressure. On the other hand, if the manometer is of the tambour type, it may have a tendency to overswing, so that systolic pressure will be recorded too high and diastolic too low. The ideal manometric system has neither appreciable inertia nor overswing, and is best realized in the apparatus described by Hamilton, Brewer and Brotman.<sup>6</sup> This method is not practicable for routine clinical use, but Steele<sup>11</sup> showed that results obtained by it confirm the reliability of the usual indirect method, as shown in Figure 10.

2. INDIRECT METHODS. (a) The usual clinical method depends upon palpation of the radial artery and auscultation of the brachial artery after occlusion of the brachial artery in the upper arm by means of an inflatable rubber cuff. Based on the work of Steele,<sup>11</sup> diastolic pressure is read at the fifth phase, disappearance of sounds, instead of at the fourth phase, change of sound. It is suggested that pressure be measured in both arms, at least the first time the patient is studied.

(b) Oscillometric methods depend upon the development and progression of oscillations while pressure is raised and lowered in a blood pressure cuff.

(c) Griffith and Collins<sup>4</sup> described a method depending upon observation of flow in the capillaries of the nail bed while pressure in a blood pressure cuff about the arm is raised and lowered. Capillary flow stops when the pressure in the cuff is raised above systolic pressure and starts again when pressure in the cuff falls below systolic pressure. It is the only indirect method for measuring pressure in an artery that is patent without pulsation, and this is the principal advantage of the method. It may also be used to show a gradient in pressure; for example, measurement with a finger cuff shows a pressure of 8 to 10 mm. lower in the digital than in the brachial artery. However, the method does not measure diastolic pressure; it is laborious and requires special equipment and skill.

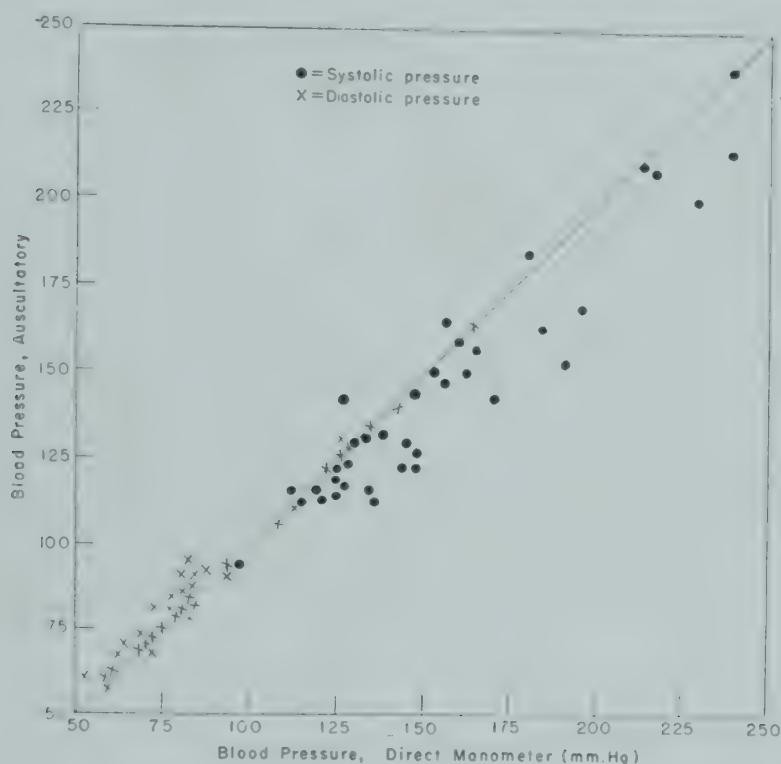


Fig. 10. (Drawn from figures of Steele.)

### LOWERMOST LEVEL OF PRESSURE

The principle for obtaining the lowermost level of blood pressure measurements is to secure physical and mental rest.<sup>5</sup> Measuring blood pressure during sleep would probably be the ideal procedure, but is rarely practicable. Lying down for half an hour will secure physical rest, but, in a nervous patient, may increase mental apprehension and so defeat its own purpose. Often the carrying out of a routine study is more relaxing for a patient than a deliberate attempt to secure complete rest. In any case, the physician should evaluate the blood pressure measurements with due regard to the patient's state.

### UPPERMOST LEVEL OF PRESSURE

Owing to emotional stress, the first blood pressure measurement obtained by an examiner previously unknown to the patient may approximate the uppermost level.<sup>7</sup> Immersing one hand in ice water may also produce an elevation

of pressure, but it is not certain that such a rise is within the usual blood pressure range, since it measures the response to an abnormal stimulus.

TABLE 8  
AVERAGE BLOOD PRESSURE OF ADULTS ACCORDING TO AGE\*  
(Symonds, 1922)<sup>12</sup>

<i>Age in Years</i>	<i>Systolic Blood Pressure</i>	<i>Diastolic Blood Pressure</i>
15-19.....	123.5	79.5
20-24.....	124.2	80.5
25-29.....	124.5	81.5
30-34.....	125.1	82.3
35-39.....	125.3	83.3
40-44.....	126.4	84.0
45-49.....	128.2	84.7
50-54.....	130.2	85.9
55-59.....	133.5	86.8
60 and over.....	135.2	86.9

\* The systolic figures are based on 150,419 apparently healthy men applying for life insurance, and the diastolic figures on 60,733.

Measurements obtained in the thigh are higher than those in the arm. Wendkos and Rossman<sup>13</sup> state that systolic pressure averages 36 mm. and diastolic 21 mm. higher in the thigh than in the arm.

Robinson<sup>10</sup> studied a number of men over a five to ten year period and found fluctuations in their systolic pressure (Table 9).

TABLE 9  
VARIATIONS IN SYSTOLIC BLOOD PRESSURE IN MEN OVER 5 TO 10 YEAR PERIOD  
(Robinson, 1940)<sup>10</sup>

<i>Systolic Blood Pressure (Mm. Hg)</i>	<i>Number of Men</i>	<i>Difference Between Highest and Lowest Readings (Mm.)</i>
Under 110.....	112	15.3
110-120.....	116	19.8
120-130.....	78	19.7
130-140.....	40	19.0
140 and over.....	28	26.6

VENOUS PRESSURE

The venous pressure may be measured by placing a small chamber with a glass top over a vein and maintaining it at the level of the right auricle. This chamber is connected with a water manometer, and the venous pressure is that which is required to cause collapse of the vein.

The venous pressure may also be measured directly by the insertion of a wide-bore needle with a manometer containing citrate solution.

The pressure in the median basilic vein shows considerable variations. The normal range is between 40 and 110 mm. of water. The pressure is greater in veins near the periphery and diminishes in those closer to the heart. The pressure in the veins is the algebraic sum of the positive pressure transmitted from

the arterial side and the negative pressure exerted upon the blood column from the thoracic cavity. The venous pressure varies as a result of the gravity effect, depending on the position of the vein with relation to the right auricle.

### CAPILLARY PRESSURE

A method for measuring capillary pressure, devised by Landis,<sup>2</sup> requires the insertion of a fine cannula into the capillary. At the level of the auricle the capillary pressure remains constant. It increases, however, when the hand is moved to a lower level. *The average pressure in the arterial limb of the capillary is 32 mm. of mercury; in the venous limb, 12 mm.* The venous pressure is lower than the osmotic pressure of the plasma. Heat, venous congestion and a histamine flare elevate capillary pressure. The application of cold causes first a fall in pressure and then a small rise above the original pressure.

### PRESSURE IN THE RIGHT AURICLE AND RIGHT VENTRICLE

Bloomfield and his co-workers<sup>1</sup> by means of a Hamilton manometer have directly recorded the blood pressures in the human heart under physiologic conditions, by the introduction of a catheter through the antecubital vein into the right auricle and right ventricle. In the resting recumbent normal subjects the mean auricular pressure varied from minus 2 to plus 2 mm. of mercury.

In the right ventricle the maximum systolic pressure in normal subjects is between 18 and 30 mm. of mercury above atmospheric pressure (average 25 mm.). The diastolic pressure ranges from minus 7 to plus 2 mm. of mercury early in diastole, to minus 0.5 and plus 4.5 mm. of mercury at the end of diastole.

### VALUES IN CHILDREN

Blood pressure measurements in children may vary from day to day. Table 10 gives normal values. Consideration should be given to the type of cuff used when measuring pressure in children. If a cuff is used which is about the same width in proportion to the size of the child's arm as the regular cuff is to the size of the average adult's arm, the readings in children are comparable to those of adults.<sup>3</sup>

TABLE 10  
BLOOD PRESSURE IN CHILDREN  
(Values from Downing, 1947)<sup>3</sup>

Age in Years	Cuff	Blood Pressure (Mm. Hg)	
		Systolic	Diastolic
5.....	Child	68 to 104	42 to 74
	Adult	68 to 88	32 to 64
10.....	Child	80 to 114	52 to 70
	Adult	72 to 120	48 to 72
15.....	Child	110 to 116	68 to 72
	Adult	94 to 114	50 to 74

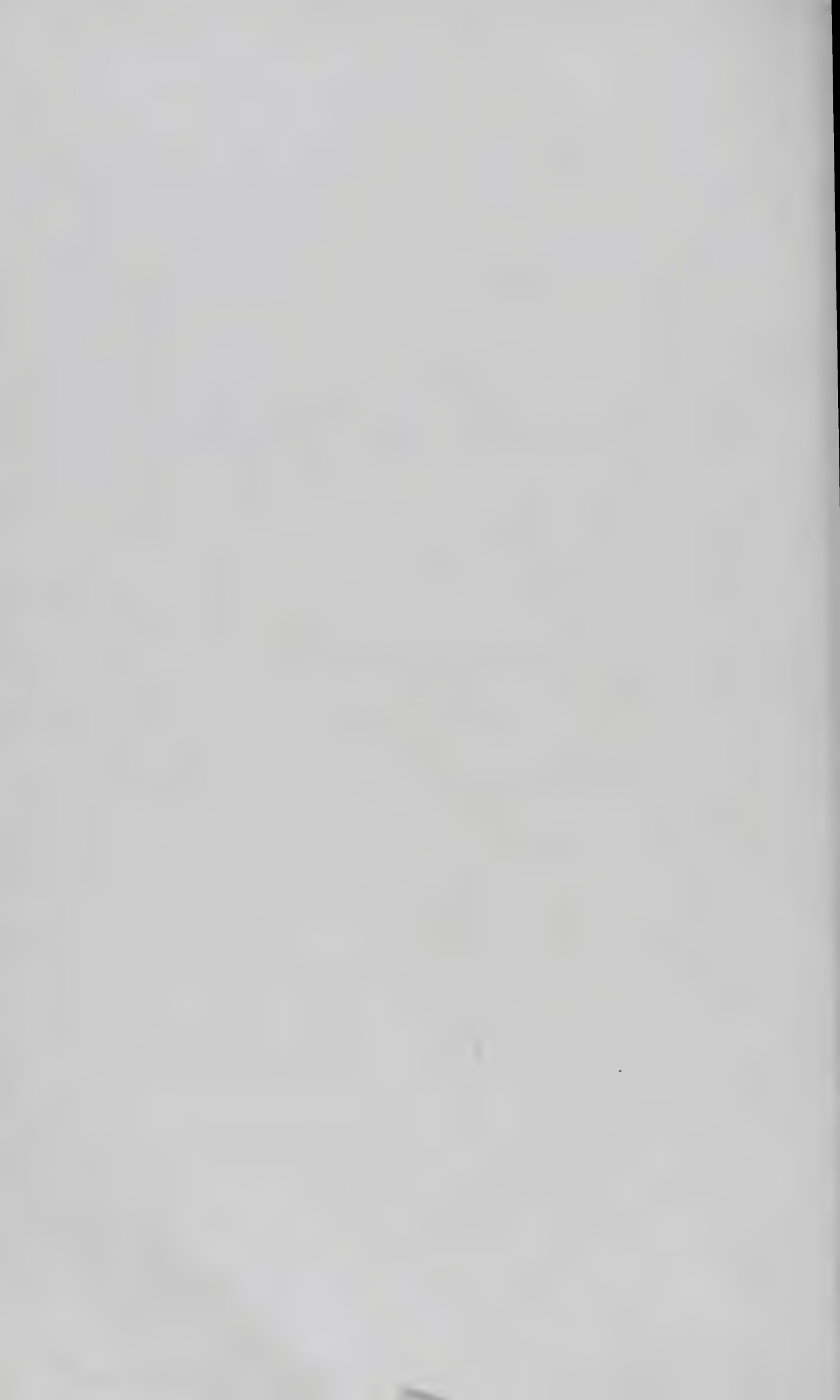
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## Section II

# BLOOD CELLULAR ELEMENTS

(Normal Values in Hematology)



## Chapter 6

### ERYTHROCYTES

#### NUMBER OF ERYTHROCYTES

THE ERYTHROCYTE count is expressed as the number of cells per cubic millimeter of blood. *The normal range for adults is:*

<i>Men: 4,600,000 to 6,200,000</i>	} (United States of America <sup>35</sup> )
<i>Women: 4,200,000 to 5,400,000</i>	
<i>Men: 4,000,000 to 6,500,000</i>	} (England <sup>36</sup> )
<i>Women: 4,000,000 to 6,000,000</i>	

In infants the count ranges from about 5,000,000 to 7,000,000 on the first day, and drops rapidly to a range of 4.23 to 6.15 million during the first month. From the second to the twelfth month the range is close to 4,000,000 to 5,500,000.<sup>17</sup>

Some investigators have observed diurnal variations; others have not. Muscular activity is usually associated with an increase in the count. Psychic factors such as fear may cause a significant increase. Abdominal massage and cold baths have the same effect. The difference in count between males and females does not become manifest until puberty. Ascent to high altitudes is usually accompanied by a rapid increase in the count (see Table 11). The rate and height of the ascent determine the degree of the increase.

TABLE 11  
NORMAL ERYTHROCYTE COUNT AT VARIOUS ALTITUDES  
(Data from Hurtado, Merino and Delgado, 1945)<sup>13</sup>

<i>Altitude</i>	<i>Number of Subjects (Males)</i>	<i>Range*</i>
Sea level.....	175	4,460,000 to 5,820,000
12,340 feet (3730 meters).....	40	4,890,000 to 6,450,000
14,900 feet (4540 meters).....	32	5,010,000 to 7,290,000

\* Plus or minus 2 × S.D.

#### HEMOGLOBIN CONCENTRATION

(See Chap. 16, p. 123)

Hemoglobin is contained in the erythrocyte. Its concentration may be expressed in grams per 100 ml. of blood on the assumption that

$$\frac{\text{Volumes per cent oxygen capacity}}{1.34^*} = \text{grams of hemoglobin per 100 ml.}$$

\* The value, 1.34, for the combining power of O. per gram of hemoglobin may be too high. See page 123.

A normal range expressed in percentage cannot be given, for there is no agreement as to the number of grams of hemoglobin per 100 ml. of blood that should represent 100 per cent normal. For clinical purposes the normal ranges are as follows:

*Men: 12 to 17 gm. per 100 ml.*

*Women: 11 to 15 gm. per 100 ml.*

In the newborn during the first day the range is from 18.8 to 28 gm. per 100 ml. The second day it falls to 11.4 to 21.4, and during the next ten months it ranges from 10 to 16 gm. per 100 ml.<sup>17</sup>

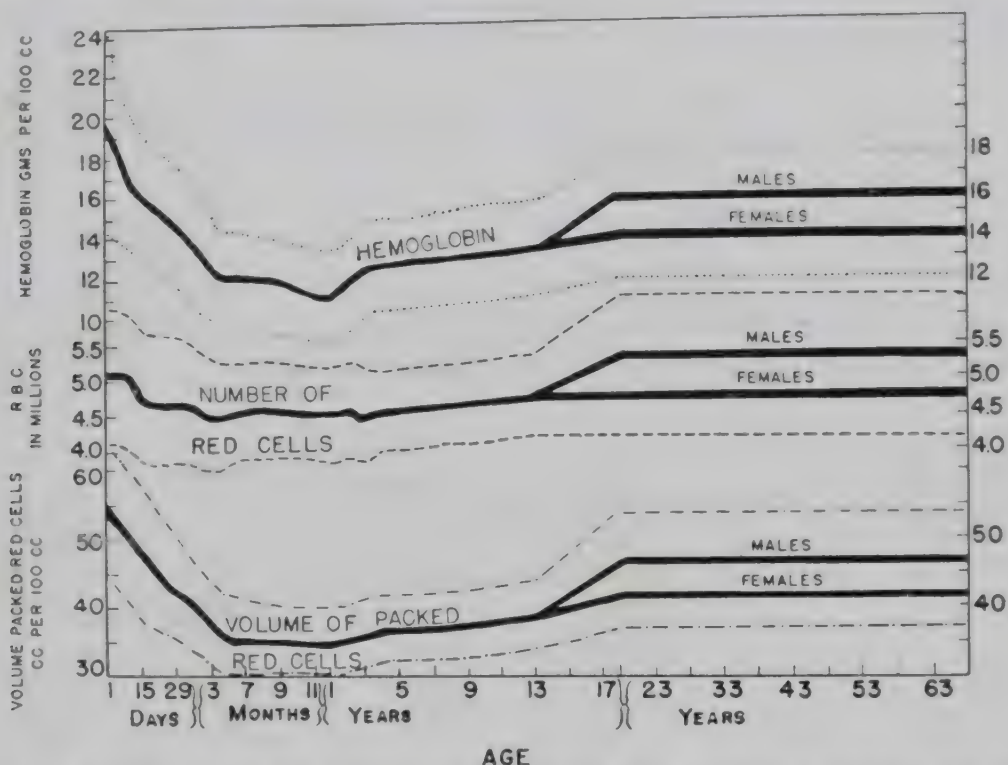


Fig. 11. Normal curve for hemoglobin, red cells and volume of packed red cells, from birth to old age. The mean values are heavily outlined. The range of variation is indicated by dotted lines for hemoglobin, interrupted lines for red cell count, and dotted interrupted lines for volume of packed red cells. The scales for hemoglobin, red cell count and volume of packed red cells are similar; therefore the relative changes in these three values are apparent on inspection. The scale for age, however, is progressively altered. (Derived from the data of Williamson, Appleton, Haden and Neff, Merritt and Davidson, Poncher, Guest, Osgood and Baker, Kato, Mugrage and Andresen, and Wintrobe.) (Wintrobe, M. M.: Clinical Hematology, Lea and Febiger.)

The difference in concentration between males and females does not occur until puberty. Some observers have claimed diurnal variations. The variations observed may have been due to physical activity, since there is little variation in the erythrocyte count or hemoglobin concentration during complete inactivity. Variations in the number and size of erythrocytes are the usual causes of variations of hemoglobin in the normal subject.

In the aged the normal range for hemoglobin may be lower than that of adults, as indicated by a study of a group of men and women between sixty-five and eighty years of age which showed the hemoglobin to vary between 9.6 and 15.4 gm. per 100 ml. (mean value plus or minus 2 times the standard deviation).

Pimenta de Mello and his co-workers<sup>26</sup> determined the hemoglobin content of the blood of 743 naval men, cadets and military personnel at Rio de Janeiro

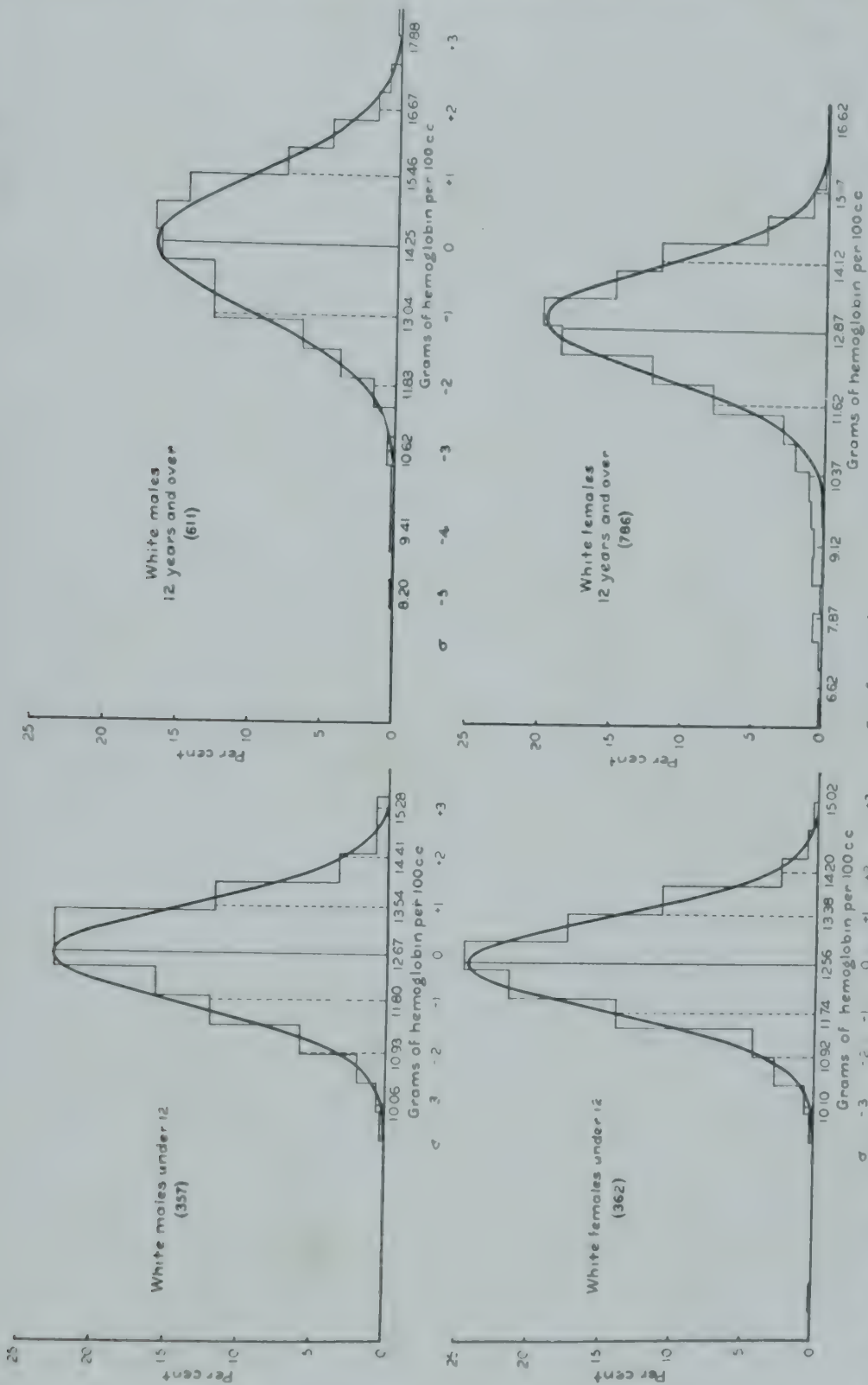


Fig. 12. Percentage of frequency distributions of hemoglobin determinations of white persons. (Milam, D. F., and Muench, H.: J. Lab. & Clin. Med., vol. 31.)

and found the range to be between 12.04 and 16.32 gm. (plus or minus 2 times the standard deviation). They also found the range in a professional group to be 10.93 to 15.65 gm. mean value plus or minus 2 times the standard deviation.

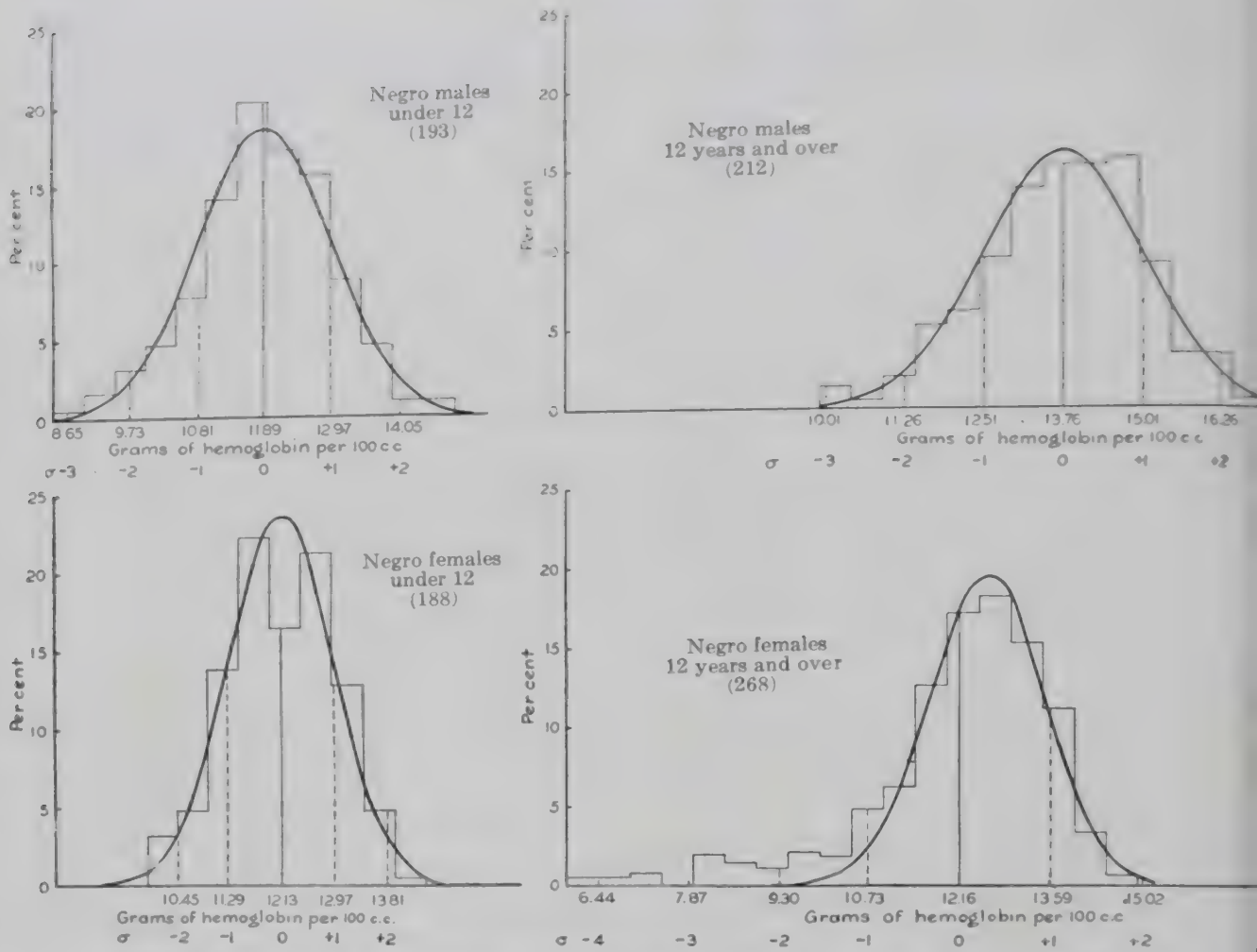


Fig. 13. Percentage of frequency distributions of hemoglobin determinations of Negro persons. (Milam, D. F., and Muench, H.: J. Lab. & Clin. Med., vol. 31.)

TABLE 12

VALUES FOR HEMOGLOBIN OF THE BLOOD OF WHITE AND NEGRO POPULATIONS  
(Milam and Muench, 1946)<sup>18</sup>

Type of Subjects	Number of Subjects	Mean $\pm$ St. Dev. (Gm. Hemogl. per Cent)	Range* (Gm. Hemogl. per 100 ml.)
White boys under 12.....	357	12.67 $\pm$ 0.867	10.93-14.40
White girls under 12.....	362	12.54 $\pm$ 0.874	10.80-14.28
Negro boys under 12.....	193	11.89 $\pm$ 1.082	9.72-14.05
Negro girls under 12.....	188	12.13 $\pm$ 0.845	10.44-13.82
White men over 12.....	611	14.25 $\pm$ 1.209	11.83-16.68
White women over 12.....	838	12.87 $\pm$ 1.254	10.36-15.37
Negro men over 12.....	212	13.76 $\pm$ 1.249	11.26-16.25
Negro women over 12.....	268	12.16 $\pm$ 1.430	9.30-15.02

\* Twice the standard deviation on either side of the mean.

Milam and Muench<sup>18</sup> studied the hemoglobin values of the normal white and Negro populations of North Carolina. Figures 12 and 13 give frequency curves for color, age and sex, and Table 12 gives hemoglobin values.

TABLE 13

ERYTHROCYTE AND HEMOGLOBIN VALUES IN BOYS AND GIRLS FROM 4 TO 13 YEARS OF AGE  
(Osgood and Baker, 1935, modified)<sup>24</sup>

<i>Age in Years</i>	<i>Sex</i>	<i>Erythrocytes</i> (Millions per Cu. Mm.)	<i>Hemoglobin*</i> (Gm.-100 Ml.)
4.....	Boys	4.11-4.47	9.41-13.0
	Girls	4.41-5.59	10.46-14.3
5.....	Boys	4.38-5.38	9.91-12.77
	Girls	4.06-5.23	9.89-12.86
6.....	Boys	4.19-5.96	10.81-12.64
	Girls	4.36-5.50	10.46-13.79
7.....	Boys	4.42-5.35	10.56-12.07
	Girls	4.14-5.68	11.03-12.93
8.....	Boys	4.60-6.02	10.07-12.81
	Girls	4.43-5.86	10.65-13.28
9.....	Boys	4.83-5.44	9.85-12.05
	Girls	4.54-5.45	10.75-13.28
10.....	Boys	4.52-6.16	10.06-14.23
	Girls	4.38-5.47	14.31-10.74
11.....	Boys	4.74-5.06	10.92-14.01
	Girls	4.37-5.65	10.57-12.74
12.....	Boys	4.66-5.80	11.19-13.52
	Girls	4.47-5.80	11.01-13.52
13.....	Boys	4.10-6.08	10.37-14.92
	Girls	4.47-5.57	11.22-14.81

\* Hemoglobin determinations were done by the method of Osgood and Haskins. All determinations were made on oxalated venous blood.

TABLE 14

NORMAL HEMOGLOBIN AT VARIOUS ALTITUDES  
(Data from Hurtado, Merino and Delgado, 1945)<sup>13</sup>

<i>Altitude</i>	<i>Number of Subjects</i> (Males)	<i>Range*</i> (Gm. per 100 ml.)
Sea level.....	175	14.40 to 17.60
12,340 feet (3730 meters).....	40	15.90 to 21.74
14,900 feet (4540 meters).....	32	17.34 to 24.18

\* Plus or minus 2  $\times$  S.D.

## SHAPE

A normal erythrocyte has the form of a biconcave disk. The shape is usually uniform, but in stained smears of normal blood an occasional oval or irregular-shaped cell may be present.

There is a familial anomaly in which many of the cells are oval or sausage-shaped. These cells have been called *elliptical cells* or *ovalocytes*. This anomaly has been demonstrated in many members of a number of families chiefly of Dutch, German or Italian parentage. It has also been reported in those of Jewish, Scotch-Irish or Negro descent. (This anomaly should not be confused with the *sickle cell trait*, which is hereditary and familial. For the incidence of this trait, see Table 15.)

Another familial anomaly occurs in which the diameter of many of the cells is smaller, and the thickness greater, than normal. These cells are called

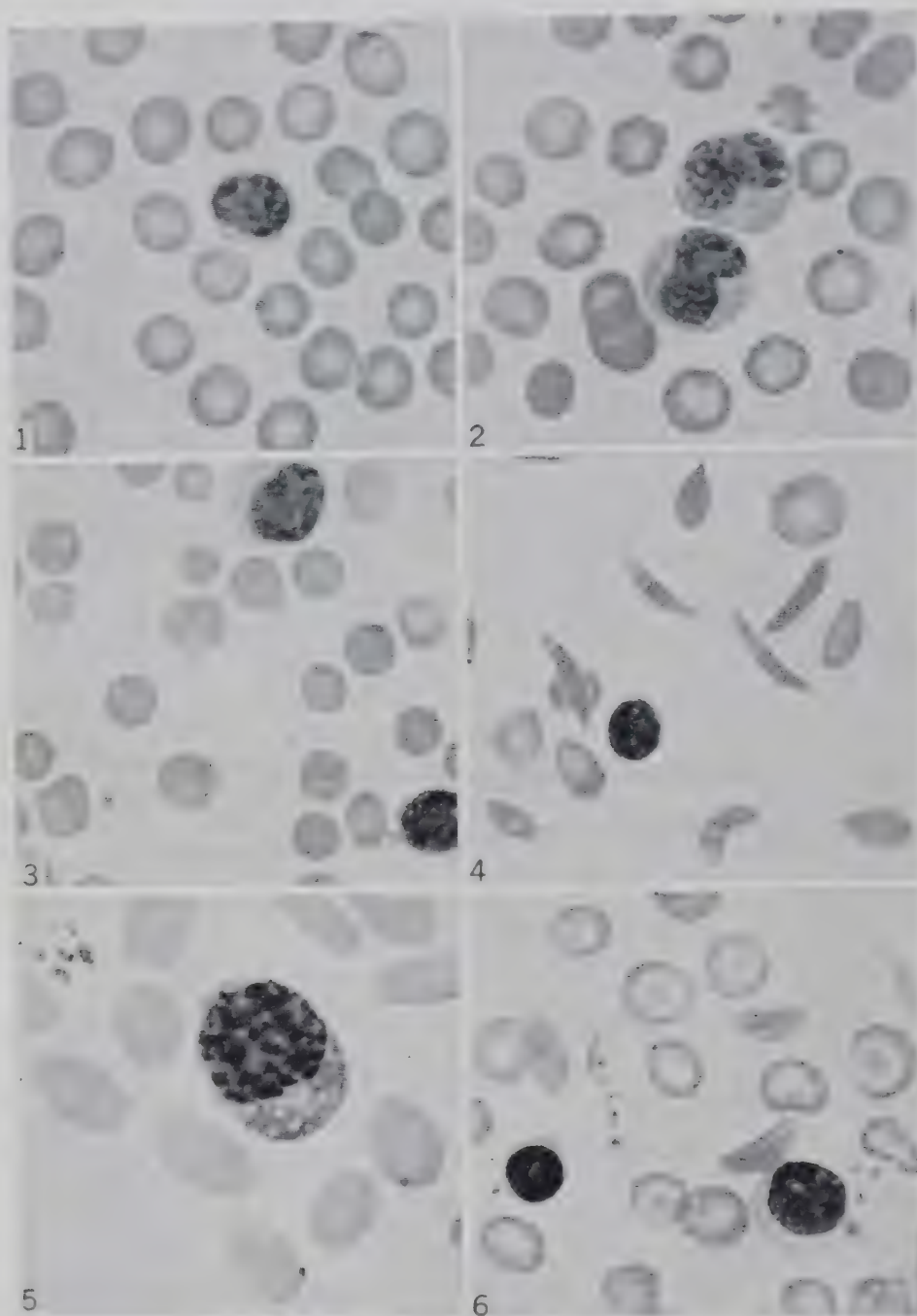


Fig. 14. Congenital abnormalities in shape of the red cell compared with normal and crenated cells ( $\times 1100$ ). 1, Normal; 2, crenated cells produced by dehydration or other injury to cells; 3, spherocytes of congenital hemolytic jaundice (the cells are decreased in diameter and increased in thickness and hemolyze more readily than normal biconcave disks); 4, sickle cells of sickle-cell anemia; 5, oval cells of oval-cell anemia; 6, peculiar "Mexican hat" or "sugar loaf" cells seen in "Mediterranean" or Cooley's anemia (this unusual appearance seems related to the sickle shape; also called "target" cells). Haden, R. L.: Principles of Hematology, Lea & Febiger.

*spherocytes*. They are more susceptible to hemolysis than are normally shaped cells.

Red corpuscles may be observed with a central rounded area of pigmented

material surrounded by a clear ring without pigment, outside of which is the usual pigmented outer border of the corpuscle. Such terms as "target" or "Mexican hat" cell have been applied to these corpuscles, which may be observed in the blood of otherwise normal persons, but more commonly in those of families of patients with Mediterranean (Cooley's) anemia.

TABLE 15  
INCIDENCE OF THE SICKLING TRAIT IN THE NEGRO POPULATION  
(Condensed from da Silva, 1945)<sup>30</sup>

Locality	Number of Subjects	Per Cent of Sickling Defect	Investigator
Alabama.....	1500	8.1	Graham and McCarty (1930)
Chicago.....	1263	9.4	Cardoso (1937)
Georgia.....	1800	5.5	Sydenstricker (1924)
Tennessee.....	2539	8.3	Diggs, Ahmann & Babb (1933)
Texas.....	1205	5.3	Killingsworth and Wallace (1936)
Rio de Janeiro.....	1130	10.0	da Silva (1945)

### MEAN CORPUSCULAR DIAMETER (M.C.D.)

The diameter of normal erythrocytes measured after fixing and staining on slides ranges from 4.75 to 9.5 microns, with an average of 7.2 microns. Cells measured in wet films are 0.8 to 1 micron greater in diameter.<sup>31</sup>

Price-Jones,<sup>27</sup> in a study of 100 healthy persons, found the average diameter in individual instances to range from 6.815 to 7.492 microns (Fig. 15). In the

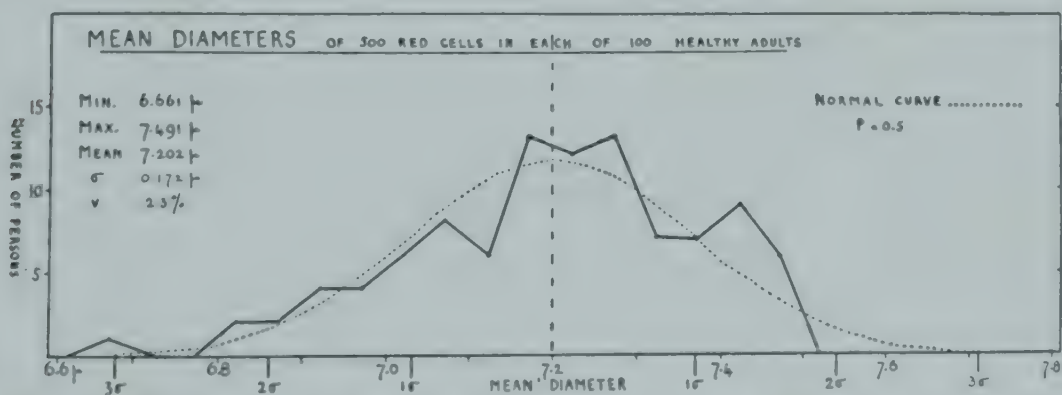


Fig. 15. Red blood cell diameters. (Price-Jones, C.: Red Blood Cell Diameters, Oxford University Press, 1933.)

majority of normal persons the range of mean cell diameters is between 7 and 7.5 microns. The chance of encountering a normal person with a mean corpuscular diameter greater than 7.718 microns or less than 6.686 microns is 1 in 1000; with a diameter greater than 7.546 microns or less than 6.858 microns it is 1 in 43.

Prolonged venous congestion increases the diameter; the use of a tourni-

quet for that purpose may cause it to increase by as much as 0.4 micron. Some normal persons always have large cells; others have small cells.

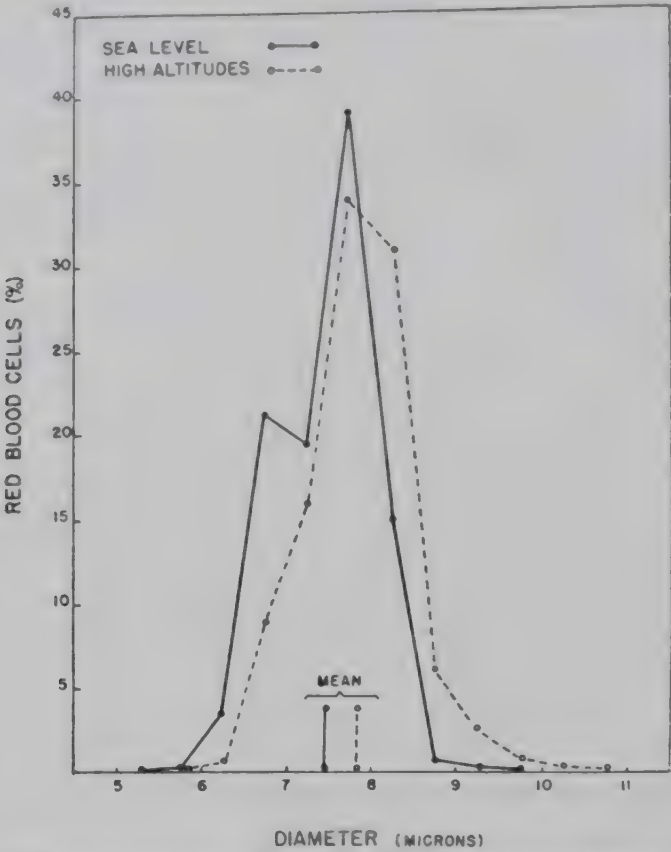


Fig. 16. Diameter of red blood cells at sea level and at high altitudes. The solid line represents measurements made for 130 healthy men living at sea level (a total of 39,400 cells measured ; the interrupted line, measurements made for 72 healthy male residents of Oroya (at 3740 meters, 12,240 feet) and Morococha (4500 meters, 14,900 feet) (a total of 17,100 cells measured . (Hurtado, A., Merino, C., and Delgado, E.: Arch. Int. Med., vol. 75.

TABLE 16

MEAN CORPUSCULAR DIAMETER OF HEALTHY MEN AT VARIOUS ALTITUDES  
(Hurtado, Merino and Delgado, 1945)<sup>13</sup>

Altitude	Number of Subjects	Range* (Microns)
Sea level.....	130	7.18 to 7.78
12,340 feet (3730 meters).....	40	7.40 to 8.36
14,900 feet (4540 meters).....	32	7.52 to 7.96

\* Plus or minus 2 × S.D.

MEAN CORPUSCULAR THICKNESS (M.C.T.)

Because of the shape of the red cells, the measurement is made by assuming that the cell has the form of a short cylinder; by so doing the concavities are balanced against the convexities.

The method of calculation is:

$$\frac{\text{Mean corpuscular volume}}{\pi\left(\frac{\text{mean diameter}}{2}\right)^2} = \text{M.C.T. (in microns)}$$

The mean value has been given as 2.14 microns<sup>7</sup> and 2.05 microns.<sup>8</sup> The normal range for adults (both sexes) may be taken as 1.7 to 2.5 microns.<sup>8</sup> Ponder<sup>9</sup> found the greatest thickness to be 2.4 microns and the least 1.02 microns.

At high altitudes the mean corpuscular thickness varies little if any from that at sea level (see Table 17).

TABLE 17

MEAN CORPUSCULAR THICKNESS OF HEALTHY MEN AT VARIOUS ALTITUDES  
(Hurtado, Merino and Delgado, 1945)<sup>13</sup>

<i>Altitude</i>	<i>Number of Subjects</i>	<i>Range* (Microns)</i>
Sea level . . . . .	130	1.85 to 2.33
12,340 feet (3730 meters) . . . . .	40	1.63 to 2.31
14,900 feet (4540 meters) . . . . .	32	1.76 to 2.40

\* Plus or minus 2  $\times$  S.D.

### MEAN DIAMETER-THICKNESS RATIO (M.D.T.R.)

The normal average ratio based on English standards is 3.4:1. The range, allowing three times the standard deviation, is from 2.4 to 4.2:1. Haden<sup>10</sup> gives the mean ratio as 4:1. According to Whitby and Britton,<sup>36</sup> ratios lower than 2.4 indicate definite spherocytosis, and a figure higher than 4.2 denotes a flat cell.

### PACKED CELL VOLUME PER 100 ML. (HEMATOCRIT READING)

The mean volume of erythrocytes represents the percentage of packed cells, determined by centrifuging for a uniform period of time (3000 revolutions per minute for thirty minutes) venous blood to which an appropriate anticoagulant has been added. The amount of packed cells per 100 ml. of blood is the figure used to express the packed cell volume.

The normal range is:

*Men, 40 to 54 per cent*  
*Women, 37 to 47 per cent*

The packed cell volume is directly affected by any changes in the number or size of the erythrocytes. This value is used to determine other corpuscular constants related to the volume of erythrocytes.

TABLE 18

NORMAL HEMATOCRIT READINGS AT VARIOUS ALTITUDES  
(Data from Hurtado, Merino and Delgado, 1945)<sup>13</sup>

<i>Altitude</i>	<i>Number of Subjects (Males)</i>	<i>Range* (Red Cells, per Cent)</i>
Sea level . . . . .	175	42.2 to 51.4
12,340 feet (3730 meters) . . . . .	40	46.3 to 61.9
14,900 feet (4540 meters) . . . . .	32	48.7 to 71.1

\* Plus or minus 2  $\times$  S.D.

### MEAN CORPUSCULAR VOLUME (M.C.V.)

The mean corpuscular volume is the average volume of a single cell expressed in cubic microns. The method for calculating it is as follows:

$$\frac{\text{Volume of packed cells in ml. per 100 ml. of blood}}{\text{Erythrocytes in millions per cu. mm.}} \times 10 = \text{M.C.V. (cu. microns)}$$

*The normal range is:*

*Both sexes, 82.3 to 100.3 microns<sup>13</sup> (see Table 19)*  
*78 to 94 cubic microns<sup>36</sup> (England)*  
*82 to 92 cubic microns<sup>38</sup> (U. S. A.)*

Cells larger than normal are called macrocytes; smaller, microcytes; and if they are within normal range, normocytes.

At high altitudes the normal range for the mean corpuscular volume is higher (see Table 19).

### MEAN CORPUSCULAR HEMOGLOBIN (M.C.H.)

Mean corpuscular hemoglobin is the average quantity of hemoglobin per cell, expressed in micromicrograms ( $\gamma\gamma$ ). A micromicrogram is a million-millionth of a gram ( $\text{Gm.} \times 10^{-12}$ ).

$$\frac{\text{Hemoglobin in grams per 100 ml. of blood}}{\text{Number of erythrocytes in millions per cu.mm.}} \times 10 = \text{M.C.H. (micromicrograms)}$$

*The normal range is:*

*Adults (both sexes), 27 to 32  $\gamma\gamma$ <sup>36</sup>*  
*27 to 31  $\gamma\gamma$ <sup>37</sup>*  
*28 to 33  $\gamma\gamma$ <sup>19</sup>*  
*27 to 35  $\gamma\gamma$ <sup>13</sup> (see Table 19)*

When the amount of hemoglobin per cell is greater than normal, the cell is designated as hyperchromic; if smaller, hypochromic; if within the normal range, normochromic.

At high altitudes the normal range is higher (see Table 19).

### MEAN CORPUSCULAR HEMOGLOBIN CONCENTRATION (M.C.H.C.)

The mean corpuscular hemoglobin concentration represents the mean hemoglobin concentration in grams per 100 ml. of packed erythrocytes. The method for calculating it is as follows:

$$\frac{\text{Hemoglobin in grams per 100 ml. of blood}}{\text{Volume of packed erythrocytes in ml. per 100 ml. of blood}} \times 100 = \text{M.C.H.C.}$$

*The normal range is:*

*Both sexes, 32 to 38 per cent<sup>36</sup>*  
*28 to 34 per cent<sup>23</sup>*  
*32 to 36 per cent<sup>38</sup>*  
*31 to 37 per cent<sup>13</sup> (see Table 19)*

High altitude does not appear to affect the concentration of hemoglobin in the cells (see Table 19).

TABLE 19

MEAN CORPUSCULAR VOLUME, HEMOGLOBIN AND HEMOGLOBIN CONCENTRATION OF  
HEALTHY MEN AT VARIOUS ALTITUDES

(Data from Hurtado, Merino and Delgado, 1945)<sup>13</sup>

Altitude	Number of Subjects	Range*		
		Mean Corpuscu- lar Volume (Cu. Microns)	Mean Corpuscu- lar Hemoglobin (Micromicro- grams)	Mean Corpuscu- lar Hemoglobin Concentration (Per Cent)
Sea level.....	175	82.3 to 100.3	27.4 to 35.0	31.3 to 36.9
2,340 feet (3730 meters).....	40	84.2 to 106.2	30.2 to 35.8	33.0 to 36.6
4,900 feet (4540 meters).....	32	84.9 to 110.1	28.9 to 38.9	32.7 to 36.7

\* Plus or minus 2 × S.D.

## VOLUME, COLOR AND SATURATION INDICES

These indices express the following ratios:

$$\text{Volume index} = \frac{\text{Mean corpuscular volume of the subject}}{\text{Normal mean corpuscular volume}}$$

$$\text{Color index} = \frac{\text{Per cent of normal hemoglobin concentration}}{\text{Per cent of normal erythrocyte count}}$$

$$\text{Saturation index} = \frac{\text{Mean corpuscular hemoglobin concentration of the subject}}{\text{Normal mean corpuscular hemoglobin concentration}}$$

Each of these ratios involves accepting normal values for comparison with the findings in the patient. Different workers have used different normal values. Sometimes normal values for the same age and sex have been used. Sometimes values have been taken in round numbers to facilitate calculation (see Tables 20 and 21). *It follows that no interpretation can be given to these indices unless the author has defined his method of calculating the index.* (The normal variability can be taken as about 8 per cent.)

TABLE 20

COLOR INDEX (C.I.)

VALUES COMMONLY USED FOR CALCULATING C.I. WITH NORMAL RANGE AND  
M.C.H. EQUIVALENT

Gm. Hb. = 100%	R.B.C. = 100%	Normal Range	M.C.H. Equivalent	Investigator
15.4.....	5,000,000	0.90-1.10	27.7-33.9	Haden (1940)
14.3.....	5,000,000	0.85-1.15	F 24.3-32.9	Osgood (1935)
14.7.....	.....	.....	M 25.0-33.9	
14.5.....	5,000,000	0.90-1.10	26.1-31.9	Wintrobe (1942)
16.6.....	5,000,000	0.80-1.00	26.7-33.3	Boerner (1939)

Since the calculation of the values of the mean corpuscular volume, hemoglobin and hemoglobin concentration does not require the use of normal figures, and all have the same clinical value, it is preferable that *the mean corpuscular volume be used in place of the volume index, the mean corpuscular hemoglobin in place of the color index, and the mean corpuscular hemoglobin concentration in place of the saturation index.*

TABLE 21  
VOLUME INDEX (V.I.)  
VALUES COMMONLY USED FOR CALCULATING V.I. WITH NORMAL RANGES AND  
M.C.V. EQUIVALENTS

<i>Cell Volume = 100%</i>	<i>R.B.C. = 100%</i>	<i>Normal Range</i>	<i>M.C.V. Equivalent</i>	<i>Investigator</i>
45.....	5,000,000	0.90-1.10	81- 99 <sup>11</sup>	Haden (1940)
F 43.....	5,000,000	0.85-1.15	F 73- 99	Osgood (1935)
M 41.....			M 70- 94 <sup>22</sup>	
43.2.....	5,000,000	0.90-1.10	78- 95 <sup>37</sup>	Wintrobe (1942)
50.....	5,000,000	0.80-1.00	80-100 <sup>1</sup>	Boerner (1939)

SEDIMENTATION RATE

The rate of settling or sedimentation of the erythrocytes in whole blood (with an anticoagulant) standing in a tube is known as the sedimentation rate.

There are two methods for measuring sedimentation rates. In one the time is arbitrarily fixed and the extent of the sedimentation during that time is recorded; in the other, the distance to be sedimented is fixed and the time taken to reach that distance is recorded. The normal range depends to some extent upon the method employed; therefore a single norm cannot be applied to all methods.

Cutler<sup>5</sup> has also used the maximum distance the erythrocytes settle during any five minute interval of a half-hour period. A maximum settling in five minutes of 1 mm. or less is normal.

INFANTS AND CHILDREN. Smith,<sup>32</sup> using his micromethod, found the range for infants and children from twelve days to fourteen years of age to be 3 to 13 mm. at the end of one hour. The range for newborn infants was usually 0 to 2 mm.

CORRECTED SEDIMENTATION RATE

Some investigators recommend adjusting the concentration of the erythrocytes to normal before conducting the test on whole blood, by the addition or removal of the patient's plasma, according to whether the packed cell volume is greater or less than normal. Wintrobe and Landsberg<sup>33</sup> measure the rate in the unaltered specimen, and then correct the rate according to the volume of packed cells by using a special chart (see Fig. 17).

TABLE 22

COMPARISON OF 5 COMMONLY USED SEDIMENTATION METHODS  
(Adapted from Ham and Curtis, 1938)<sup>12</sup>

	<i>Rourke and Ernstene (1930)</i>	<i>Winrobe and Landsberg (1935)</i>	<i>Westergren (1920)</i>	<i>Linzenmeier (1920)</i>	<i>Cutler (1926)</i>
Sedimentation tube:					
Length.....	120 mm.	120 mm.	300 mm.	65 mm.	70 mm.
Internal diameter.....	4.0 mm.	2.5 mm.	2.5 mm.	5.0 mm.	5.0 mm.
Graduations.....	0-100 mm.	0-100 mm.	0-200 mm.	0-18 mm.	0-50 mm.
Height of blood column.....	100 mm.	100 mm.	200 mm.	50 mm.	50 mm.
Anticoagulant	Heparin, 1.5 per cent Dry oxalate mixture Potassium oxalate	Dry oxalate mixture	Sodium citrate, 3.8 per cent	Sodium citrate, 5 per cent	Sodium citrate, 3 per cent
Amount	0.013 cc. heparin in 3 cc. blood		0.2 cc. in 1.0 cc. mixture	0.2 cc. in 1.0 cc. mixture	0.1 cc. in 1.0 cc. mixture
Concentration (mg. per 100 cc. mixture)	65 heparin 200 oxalates	200	760	1000	300
Dilution of blood (per cent)	0.4 heparin 0.0 dry oxalate mixture	0	20	20	10
Method of timing.....	Slope of period of con- stant fall	Distance settled in 1 hour	Distance settled in 1 hour	Time to settle to 18 mm.	Graph of curve and dis- tance settled in 1 hour
Sedimentation rate units.	Millimeters per minutes	Millimeters	Millimeters	Minutes	Slope of curve and millimeters
Correction for erythrocyte concentration	Required	Required	Seldom used	None	None
Normal range	0.05-0.40 mm. per min.	0.9 mm. men 0-15 mm. women	1-3 mm. men 4-7 mm. women	200-600 min.	"Horizontal line" and 2-8 mm. men 2-10 mm. women

## RETICULATED ERYTHROCYTES [RETICULOCYTES]

Reticulocytes are non-nucleated erythrocytes which are not fully matured. When stained by special methods ("vital staining"), they show basophilic material in the form of skeins. The reticulocyte is slightly larger than the adult

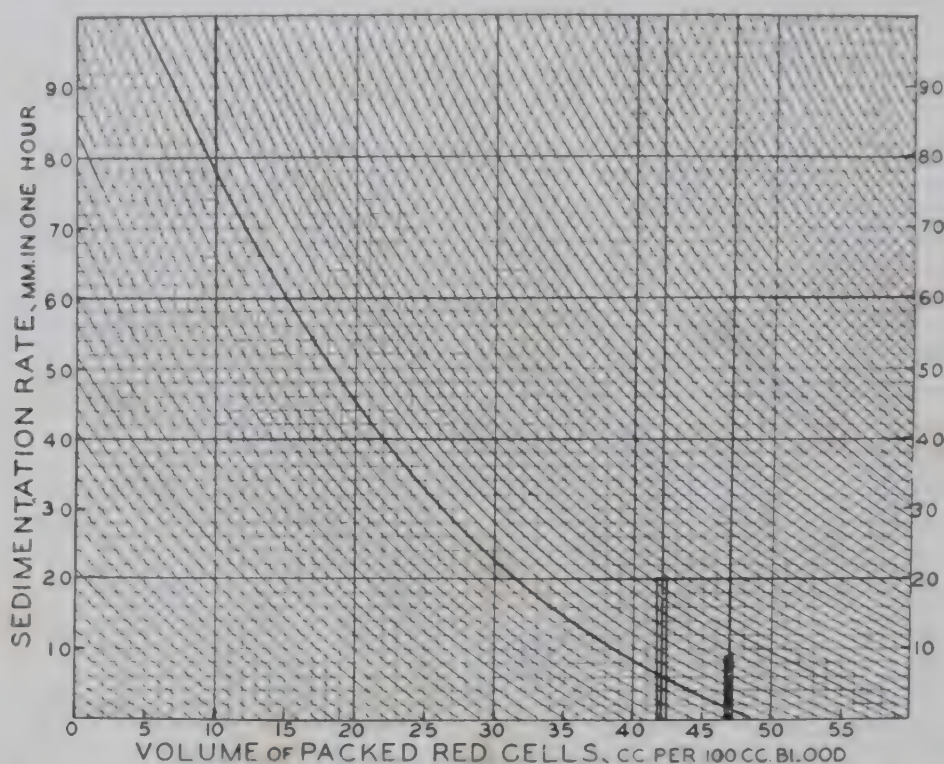


Fig. 17. Volume of packed red cells, cubic centimeters per 100 cc. of blood. The logarithmic curve on which the chart is based is heavily outlined. The mean normal value of packed red cells for men (47 ml.) and women (42 ml.) are also heavily outlined, and the range of normal sedimentation is represented by solid and open columns for each sex, respectively.

To "correct" the sedimentation rate, find on the chart the horizontal line corresponding to the sedimentation rate for the patient; find also the vertical line corresponding to the volume of the packed red cells in the patient's blood. Select the curve lying nearest the point of junction of the horizontal and vertical lines and follow this to the normal line for the sex of the patient. The horizontal line corresponding to this last point of juncture gives the corrected sedimentation rate. Since the difference between the normal sedimentation rates in men and women is largely due to the difference in volume of packed red cells, all sedimentation rates may be corrected to a volume of 47 cc. and a single standard of normal (0 to 6 mm.) used. (Wintrobe, M. M., and Landsberg, J. W.: *Am. J. M. Sc.*, vol. 189.)

erythrocyte. The reticulocyte count is regarded as the percentage of erythrocytes containing this basophilic material among the total erythrocytes observed. *Normal ranges reported are as follows:*

*Adults and children, 0.5 to 1.0 per cent<sup>11</sup>*  
*0.5 to 1.5 per cent<sup>38</sup>*  
*0 to 2.0 per cent<sup>28</sup>*  
*0.5 to 3.0 per cent<sup>22, 23</sup>*

Newborn infants may have counts as high as 2 to 4.8 per cent, usually falling to the adult level in two to five days.<sup>17</sup> It is said that healthy persons show a slight increase of reticulocytes during the spring months. The normal count is higher at high altitudes than at sea level (see Table 23), and an increase may occur during normal pregnancy.

TABLE 23  
RETICULOCYTE COUNT OF HEALTHY MEN AT VARIOUS ALTITUDES  
(Hurtado, Merino and Delgado, 1945)<sup>13</sup>

Altitude	Number of Subjects	Range*	
		Per Cent	Thousands per Cu. Mm.
Sea level . . . . .	93	0 to 1.1	0 to 45.2
2,340 feet (3730 meters) . . . . .	40	0 to 1.8	0 to 86.6
4,900 feet (4540 meters) . . . . .	32	0.3 to 2.7	0 to 173.2

\* Plus or minus  $2 \times \text{S.D.}$

### FRAGILITY (HEMOLYSIS) OF ERYTHROCYTES

The fragility of erythrocytes is tested by observing the beginning and the completion of hemolysis when the cells are placed in hypotonic saline solutions of variable concentrations.

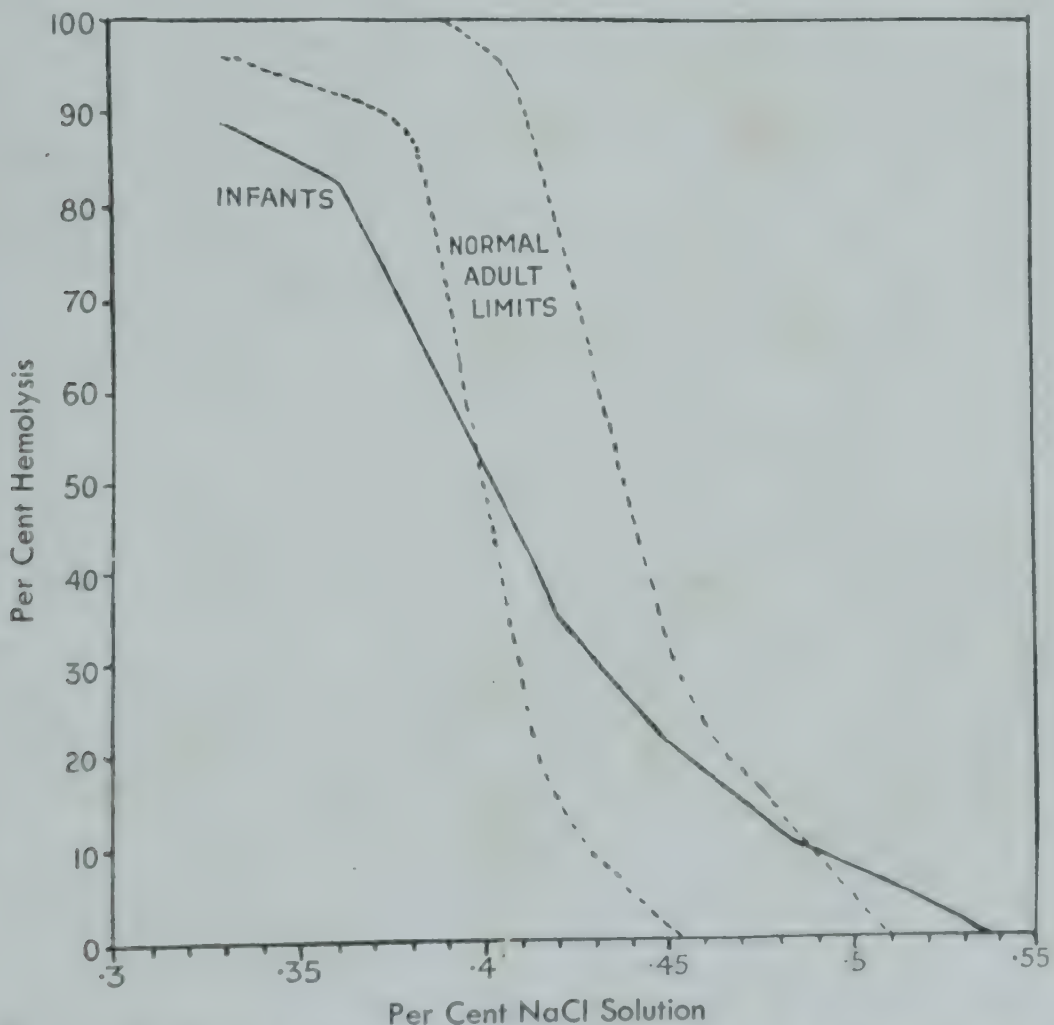
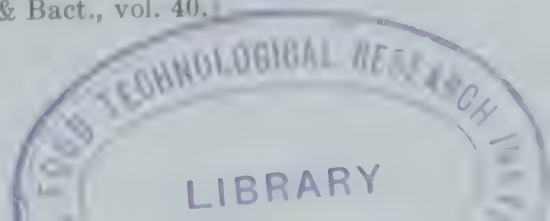


Fig. 18. Fragility of human corpuscles as determined by a quantitative method.  
(Whitby, L. E. H., and Hynes, M.: J. Path. & Bact., vol. 40.)



The normal range is:

*Slight hemolysis begins at 0.45 to 0.39 per cent sodium chloride.*  
*Complete hemolysis occurs at 0.33 to 0.30 per cent sodium chloride.*

The fragility of cells from venous blood which has not been thoroughly oxygenated is said to be greater than that of cells from arterial blood. The corpuscles of the newborn are more fragile than those of adults. Increased fragility is intimately related to the shape of the cells: the more spherical the corpuscle, the more fragile it is; the flatter the cell, the more resistant to hemolysis.

TABLE 24  
RÉSUMÉ OF NORMAL ERYTHROCYTES\*

Total number	Male, 4.5 to 6 million Female, 4 to 5.5 million
Hemoglobin concentration	Male, 12 to 17 gm. Female, 11 to 15 gm.
Mean corpuscular diameter	7 to 7.5 microns
Mean corpuscular thickness	1.7 to 2.5 microns
Diameter-thickness ratio	2.4:1 to 4.2:1
Packed cell volume	Male, 40 to 54 per cent Female, 37 to 47 per cent
Mean corpuscular volume	82 to 97
Mean corpuscular hemoglobin	27 to 33
Mean corpuscular hemoglobin concentration	32 to 36
Reticulocytes	0 to 2 per cent
Fragility (%NaCl)	Begins at 0.45 to 0.39 Complete 0.33 to 0.30
Sedimentation rate (1 hour)	Male, 2 to 8 mm. Female, 2 to 10 mm. (see also Table 22)
Color index	See Table 20
Volume index	See Table 21

\* The values given in this table are those used by the authors.

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## Chapter 7

### LEUKOCYTES

#### TOTAL COUNT

THE TOTAL leukocyte count is expressed as the number of leukocytes per cubic millimeter of blood. *The normal range for adults (both sexes) is usually given as 5000 to 10,000 per cubic millimeter.*

The total count is high at birth: some normal infants may have a count of 20,000 or even higher (see Table 27 and Fig. 19). Table 26 gives the count in children at various ages.

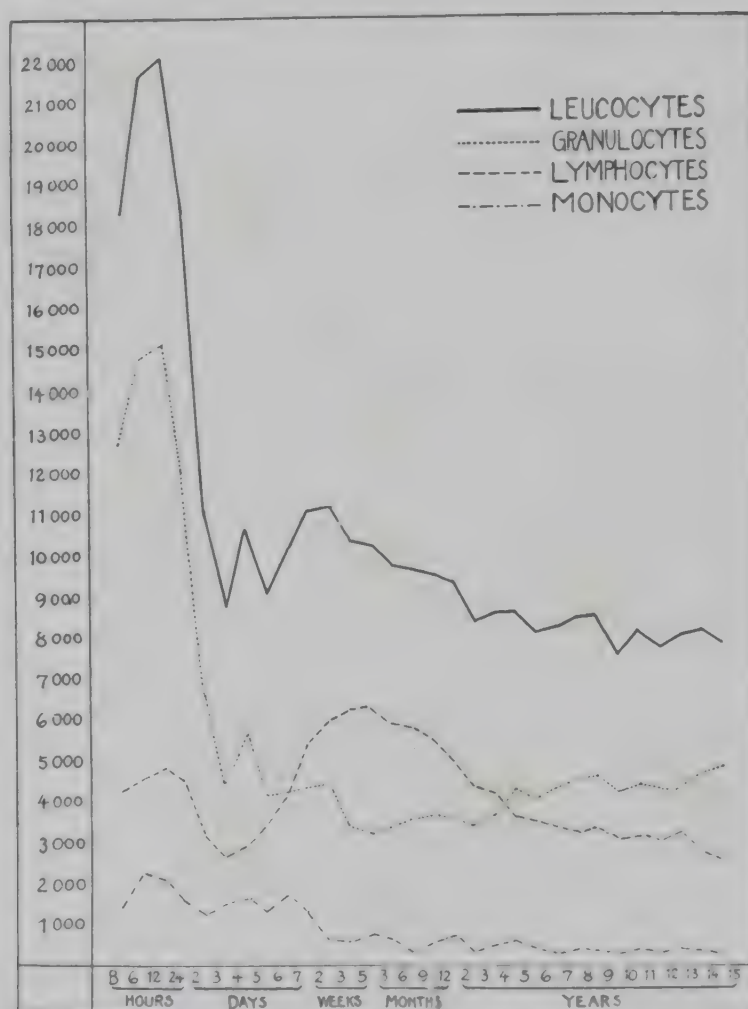


Fig. 19. Curves of average total leukocyte counts from birth to 15 years of age (1037 subjects). (Kato, K.: J. Pediat., vol. 7.)

Under basal conditions the leukocyte count is stable, but muscular or mental exercise, exposure to the sun, cold baths, ultraviolet rays and other factors are alleged to cause changes in the count. Extreme muscular exercise and pregnancy may cause a significant increase above the normal range, arising chiefly from an increase in neutrophils.

When a person ascends to high altitudes, a temporary increase in the total leukocyte count occurs about twenty-four hours after arrival, but the count returns to normal within one or two days. All types of cells are increased. Residents of high altitudes have counts similar to those of persons living at sea level.<sup>6</sup>

NEUTROPHILS (POLYMORPHONUCLEAR NEUTROPHILIC LEUKOCYTES)

The neutrophils are the predominating leukocytes in the normal blood (60 to 70 per cent). The normal range for adults (both sexes) may be taken as 3000 to 7000 per cubic millimeter. For children at various ages, see Table 26.

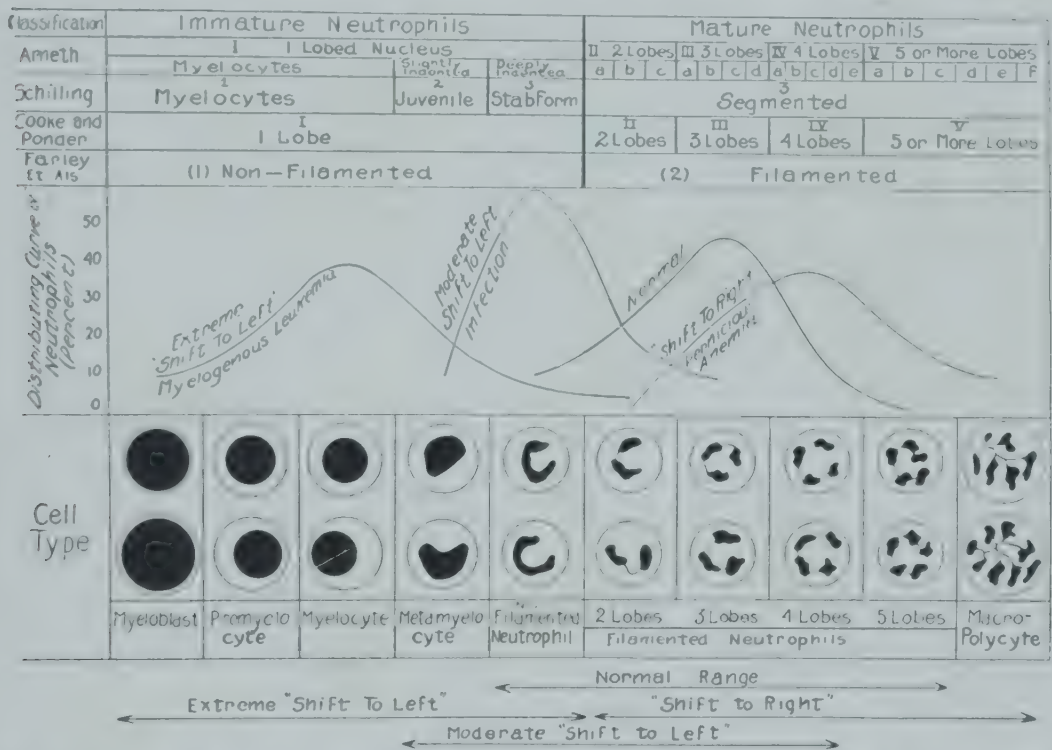


Fig. 20. Composite chart correlating the different classifications of the neutrophilic leukocytes. Note that all agree in a common dividing line between mature and immature cells. The Schilling, Pons and Krumbhaar classifications further subdivide only the immature cells. The Cooke, Ponder and the Arneth classifications further subdivide only the more mature cells. (Haden, R. L.: Principles of Hematology, Lea & Febiger.)

At birth the percentage of neutrophils is often high. In the first few days of life their number falls rapidly, while at the same time there is an increase in lymphocytes. The curves of the two types of cells cross between the sixth and twelfth days (Fig. 19).

According to Sabin there are "diurnal tides" of the neutrophils, the highest number occurring between 10 and 11 A.M. and again between 11 and 12 P.M.

During pregnancy, especially in the third trimester, an increase may occur well above the normal range. This increase is not so evident during the first and second trimesters.

**ARNETH CLASSIFICATION.** The neutrophils are grouped into five classes according to the number of lobes of their nuclei. Each group is further sub-

divided according to the shape of the lobes. An increase in those with few lobes at the expense of those with more lobes is known as a "shift to the left," and the reverse is a "shift to the right."

SCHILLING CLASSIFICATION. This, a simplification of the Arneth classification, is more applicable to routine differential counts. A differential count including the distribution of cells according to this classification is known as a Schilling "hemogram." The Schilling "index" is the ratio of the immature (myelocytes, juvenile and stab cells) to the mature (segmented) neutrophils. *The normal ratio can be taken as 1:13 or more.* Schilling expresses the index as a fraction; e. g., 1/13.

TABLE 25  
SCHILLING HEMOGRAM

	<i>Baso- phils</i>	<i>Eosino- phils</i>	<i>Myelo- cytes</i>	<i>Juvenile (Meta- myelo- cytes)</i>	<i>Stabnu- clear Neutro- phils</i>	<i>Seg- mented Neutro- phils</i>	<i>Lympho- cytes</i>	<i>Mono- cytes</i>
Normal Limits (per cent) . . . .	0-1	2-4	..	0-1	3-5	51-67	21-35	4-8

PONS AND KRUMBHAAR CLASSIFICATION. The neutrophils in this classification are divided into three groups: (1) metamyelocytes or young forms, with only a slight indentation of the nucleus; (2) nonsegmented or young neutrophils, corresponding to Schilling's stab forms; and (3) segmented or mature neutrophils.

COOKE AND PONDER CLASSIFICATION. In this classification five groups are recognized: group 1, one lobe; group 2, two lobes; group 3, three lobes; group 4, four lobes; group 5, five or more lobes.

FARLEY, ST. CLAIR AND REISINGER CLASSIFICATION. This is the simplest classification, since it divides the cells into only two classes: those without a filament between the lobes and those with a threadlike filament. When the neutrophils are grouped this way, the count is commonly known as the filament-nonfilament count.

EOSINOPHILS (POLYMORPHONUCLEAR EOSINOPHILIC LEUKOCYTES)

*The normal range for adults (both sexes) may be taken as 50 to 500 per cubic millimeter. For children at various ages, see Tables 26 and 27.*

According to Naegeli,<sup>2</sup> it is difficult to find eosinophils during a fasting period in a normal person. A constant increase in eosinophils may be found as a familial anomaly.

BASOPHILS (POLYMORPHONUCLEAR BASOPHILIC LEUKOCYTES)

*The normal range for adults (both sexes) may be taken as 0 to 50 per cubic millimeter. For children at various ages, see Tables 26 and 27.*

## MONOCYTES

The normal range for adults (both sexes) may be taken as 100 to 600 per cubic millimeter. For children at various ages, see Tables 26 and 27.

## LYMPHOCYTES

The normal range for adults (both sexes) may be taken as 1000 to 3000 per cubic millimeter. For children at various ages, see Tables 26 and 27.

TABLE 26  
NORMAL RANGES OF LEUKOCYTES IN CHILDREN AND ADULTS  
(Kolmer and Boerner, 1945)<sup>3</sup>

	3 Months to 3 Years	3 Years to 5 Years	5 Years to 15 Years	Adults
Total count.....	7500-14,000	6000-12,500	5500-10,800	5000-10,000
Neutrophils.....	2000-7000 (26-50%)	2500-7000 (40-50%)	3000-7000 (55-65%)	3000-7000 (60-70%)
Eosinophils.....	75-700 (1-5%)	60-600 (1-5%)	55-500 (1-5%)	50-400 (1-4%)
Basophils.....	0-140 (0-1%)	0-125 (0-1%)	0-100 (0-1%)	0-50 (0-1%)
Lymphocytes.....	4000-9000 (52-64%)	2500-6000 (34-48%)	1500-4500 (28-42%)	1000-3000 (20-30%)
Monocytes.....	75-840 (1-6%)	60-750 (1-6%)	55-600 (1-6%)	100-600 (2-6%)

TABLE 27  
RANGE OF LEUKOCYTES IN INFANTS  
(Forkner, 1929)<sup>4</sup>

	1st Day (13 Cases)	3rd to 5th Day (9 Cases)	6th to 8th Day (10 Cases)	9th to 11th Day (10 Cases)
Total count.....	15,250-45,000	4000-18,800	7600-16,400	8100-16,500
Neutrophils.....	8628-33,525 (53-82.5%)	1800-10,152 (32-59%)	2156-8528 (26.5-67%)	1976-6141 (18.5-46%)
Eosinophils.....	0-895 (0-6%)	168-1110 (1.5-13%)	160-727 (1.5-7%)	205-873 (1.5-6.5%)
Basophils.....	76-636 (0-4%)	0-215 (0-2%)	0-196 (0-1.5%)	0-269 (0-2%)
Lymphocytes.....	2000-8722 (5-56%)	600-5184 (15-44.5%)	1292-7015 (17-61%)	2937-9453 (22-69%)
Monocytes.....	696-5175 (15-34%)	920-4324 (10-23%)	760-2362 (7-19.5%)	1164-3738 (8.5-28%)
Neutrophilic Myelocytes.....	0-1908 (0-13%)	0-174 (0-1.5%)	0-437 (0-3%)	0-102 (0-1%)

## DIFFERENTIAL COUNT

The purpose of the differential count is to determine the percentage of the various types of leukocytes present in the circulating blood. The percentage obtained may be used with the total count to calculate the number of each type of cell per cubic millimeter of blood. It has been the custom to report the per-

centage of each type of cell. The method of reporting in absolute numbers is preferred because the percentages reflect only relative changes; furthermore, the percentages given as normal are applicable only when the total count is within the normal range of 5000 to 10,000. Tables 26 and 27 give the normal ranges for the various leukocytes in adults and children.

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## Chapter 8

### HEMOSTATIC FUNCTION OF THE BLOOD

THE METHODS in general use to test hemostatic function are of two types:

1. Methods involving the application of a stress and measuring the response of the body to that stress. These are:
  - (a) Bleeding time of the skin
  - (b) Bleeding time of the skin after artificially raising the capillary and venous pressure: the venostasis bleeding time
  - (c) Petechial reaction of the skin: the resistance offered by the small skin vessels to rupture when the capillary and venous pressure are raised for a given period of time, or negative pressure is applied to the skin
2. Methods designed to measure the amount and quality of the various factors contributing to the mechanism of hemostasis:
  - (a) Coagulation time of the blood
  - (b) Rate and degree of retraction of the clot
  - (c) Number and type of platelets
  - (d) Amount of prothrombin
  - (e) Antithrombin content of plasma
  - (f) Fibrinogen content of plasma

#### BLEEDING TIME

The bleeding time is the time it takes a cut of the skin of uniform depth and length to stop bleeding. The following values have been given (both sexes):

0.5 to 3 minutes<sup>10</sup>  
1 to 3 minutes<sup>7</sup>

0 to 6 minutes (2  $\times$  S.D.)<sup>25</sup>  
0 to 6.4 minutes<sup>1</sup>

Pauwen and his co-workers<sup>19</sup> found the mean bleeding time (ear cuts, mean of ten simultaneous determinations in each subject) in 100 persons (fifty women and fifty men) as follows:

Men, 0.76 to 4.6 minutes  
Women, 0.80 to 4.4 minutes

#### VENOSTASIS BLEEDING TIME

A cut of standard length and depth is made with a sharp automatic lancet on the volar surface of the skin of the forearm while the upper arm is compressed by the band of a sphygmomanometer, the pressure being maintained at 40 mm. of mercury. The outcoming blood is taken up in an absorbent paper

at fifteen or thirty second intervals. The time taken for such a cut to stop bleeding is the venostasis bleeding time of the skin.

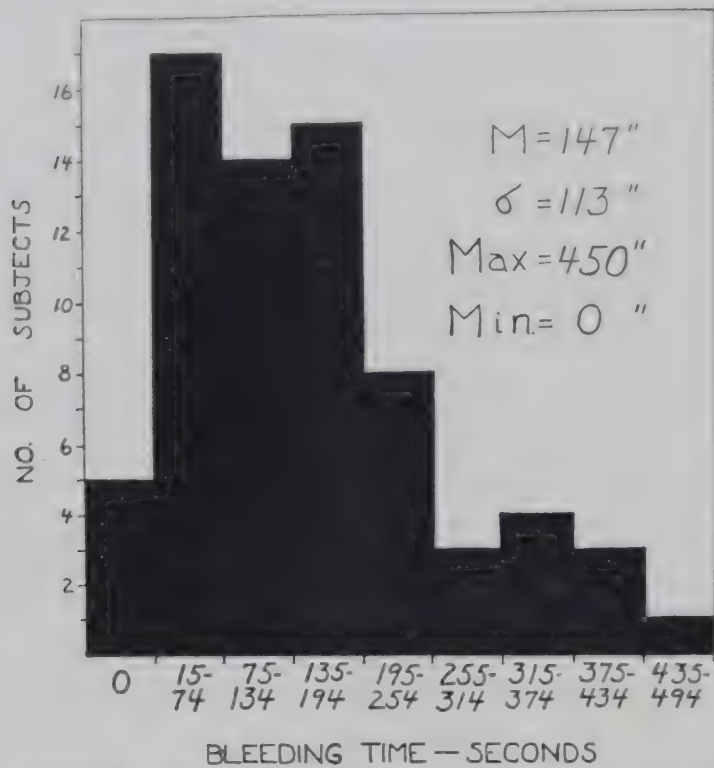


Fig. 21. Frequency histogram for standard bleeding time of cuts of uniform size in the skin of the forearm of 70 adults. (Tocantins, L. M.: M. Clin. North America, vol. 30.

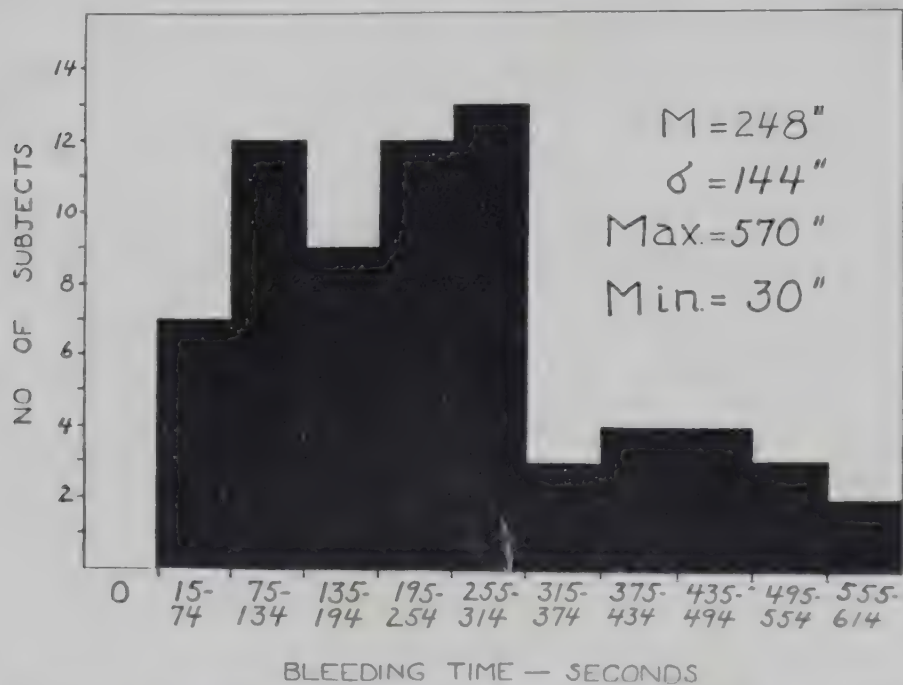


Fig. 22. Frequency histogram for venostasis bleeding time of cuts of uniform size in the skin of the forearm during compression (40 mm. Hg) of the arm in 70 adults. (Tocantins, L. M.: M. Clin. North America, vol. 30.

Ivy and his co-workers<sup>3</sup> found the bleeding time of the skin of the forearm to range from 0 to 310 seconds.

In seventy adults of both sexes studied by Tocantins<sup>5</sup> the norms for the venostasis bleeding time were found to lie between 0 and 540 seconds (2 times the standard deviation).

The depth of the cut, the sharpness of the lancet, the pressure applied with it to the skin and, to some extent, the region of the body, influence the duration of the bleeding time.

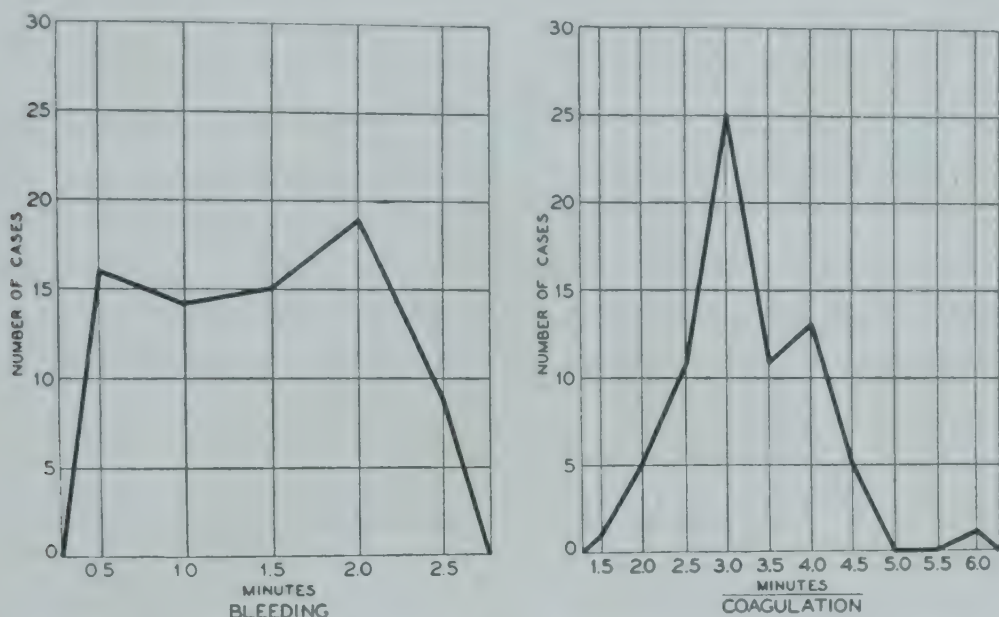


Fig. 23. Frequency distribution of values for the bleeding time and coagulation time of cutaneous blood at birth. (Merritt, K. K., and Davidson, L. T.: *Am. J. Dis. Child.*, vol. 46.)

### PETECHIAL REACTION OF THE SKIN (CAPILLARY RESISTANCE OR FRAGILITY TEST)

Two methods have been principally employed to observe this reaction of the skin:

1. The capillaries and veins of the forearm are distended by applying compression around the upper arm for a given period of time. Usually the pressure is adjusted at the level of the diastolic blood pressure. These tests cannot be repeated in the same area at less than weekly intervals. The results have been expressed in terms of the number of petechiae in a given area of the forearm at the end of a uniform period of compression.

*The normal for both sexes is up to twelve petechiae in an area of the skin of the forearm 6 cm. in diameter after compression of the arm for two 15 minute periods, first with 35 mm., then with 50 mm. of mercury pressure, with a rest period of one hour in between.*<sup>6</sup>

Lewis and Harmer<sup>13</sup> found that, to break the small vessels of the skin in normal subjects, it is necessary to exert a pressure from within of at least 90 mm. of mercury for three minutes.

2. Negative pressure is applied with a suction cup to a given area of the skin and petechiae are looked for. To a large extent the skin determines the kind of reaction. Less pressure is required in certain areas of the body where the skin is looser and thinner than in others where it is tougher and more resist-

ant to stretching. The resistance of the capillaries is higher in the legs than in the upper part of the body; the skin of the newborn stands higher negative pressure than that of older infants. The difference in response in normal persons, however, is so great that the method must be standardized in large groups to obtain the range of variation. Moreover, the values secured in a single reading can have little significance unless the normal for each subject is known. Repeated readings on the same subject may yield significant information.

The results have usually been expressed in terms of the least negative pressure applied for a standard period required to bring out macroscopic petechiae. Dalldorf<sup>3</sup> found that as little as 100 mm. or as much as 500 mm. of mercury might be necessary to bring out skin petechiae. Using Dalldorf's method, Aggeler and his co-workers<sup>1</sup> found the normal range to be 0 to 10 petechiae.

Frontali<sup>5</sup> used a suction cup 1 cm. in diameter and exerted a negative pressure up to 250 mm. of mercury for one minute. Under these conditions the following readings (expressed in millimeters of mercury, negative pressure) were obtained in the skin of the antecubital space:

- Newborn: No petechiae at less than 250 mm.
- Children (two to ten years of age): Petechiae appeared between 200 and 250 mm.
- Adults (twenty-two to thirty-six years of age): Petechiae appeared between 150 and 200 mm.

TABLE 28

FREQUENCY DISTRIBUTION (IN PER CENT) OF THE NEGATIVE PRESSURES REQUIRED TO BRING OUT PETECHIAE IN THE SKIN OF DIFFERENT REGIONS OF THE BODY IN 100 NORMAL SUBJECTS

(Adapted from Lindquist, 1937)<sup>14</sup>

Negative Pressure (Mm. Hg)	Forehead	Infraclavicular Fossa	Antecubital	Lumbar Region
50.....	41.4	85.0	3.1	24.7
100.....	45.5	14.0	57.1	65.9
200.....	9.1	1.0	36.7	8.2
300.....	2.0	.....	3.1	1.2
400.....	2.0	.....		

TABLE 29

MEAN LOWEST NEGATIVE PRESSURE (MM. HG) REQUIRED TO BRING OUT PETECHIAE IN THE SKIN OF DIFFERENT REGIONS OF THE BODY IN 240 CHILDREN (NEWBORN TO AGE 12)

(Modified from Lindquist, 1937)<sup>14</sup>

Age	Forehead	Infraclavic- ular Region	Umbilical Region	Ante- cubital	Scapular Region	Gluteal Region
1 Month.....	500	425	500	500	500	500
6 Months.....	150	150	475	188	91	375
1 Year.....	175	71	191	156	68	200
5 Years.....	75	28	80	100	40	
10 Years.....	65	34	63	96	34	

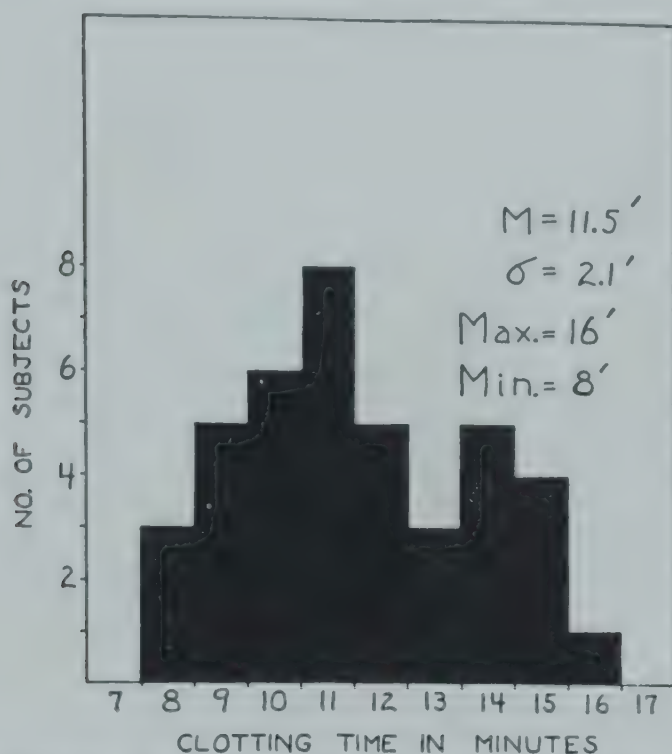


Fig. 24. Frequency histogram for the clotting time in 40 adults of 1 cc. of venous blood in glass tubes. (Tocantins, L. M.: M. Clin. North America, vol. 30.)

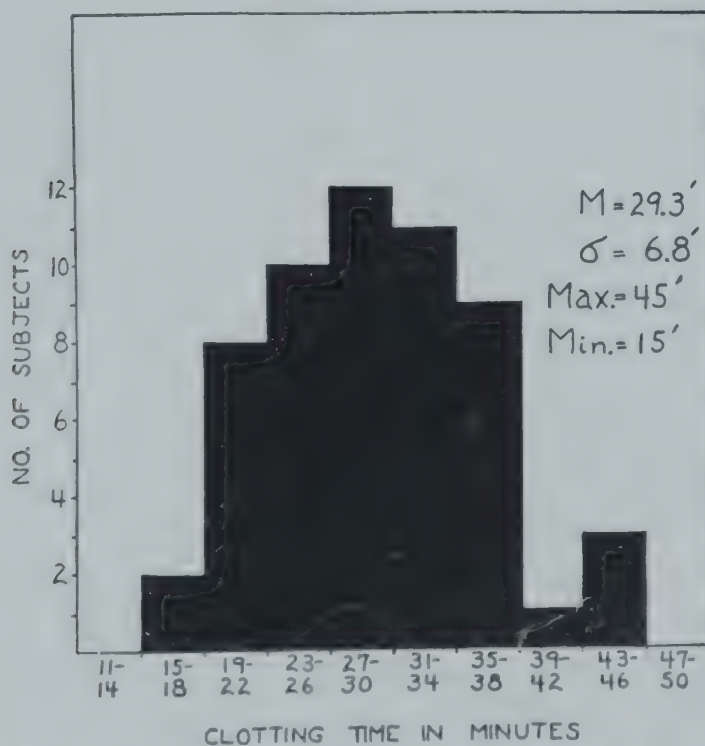


Fig. 25. Frequency histogram for the clotting time in 56 adults of 1 cc. of venous blood in paraffin-coated tubes. (Tocantins, L. M.: M. Clin. North America, vol. 30.)

Lindquist<sup>10</sup> used a cup 1 cm. in diameter and looked for the appearance of petechiae in a given area after application for one minute of negative pressure (see Tables 28 and 29).

COAGULATION TIME OF THE BLOOD

Two sources of blood have been used for measuring the coagulation time, cutaneous and venous. Table 30 lists representative examples of the results obtained by various methods. Figures 24 and 25 give the frequency distribution histograms for these values by one method.

TABLE 30  
VALUES FOR THE COAGULATION TIME OF CUTANEOUS AND VENOUS BLOOD ESTIMATED BY VARIOUS METHODS

Source of Blood	Temperature	Range (Minutes)	Number of Subjects	Remarks	Investigator
Skin incision...	37°C.	6-10	..	Capillary glass tubes	Wright (1893)
Skin.....	18-32°C.	2-4	24	Glass test tubes	Lee and White (1913)
Skin.....	37°C.	1.5-3	198	First drop of blood observed: Gibb's method, 1923	Christie (1927)
Skin.....	..	3-5	115	Bogg's method, 1908	Ivy, Shapiro and Melnick (1935)
Vein.....	18-32°C.	5-8	24	Glass test tubes	Lee and White (1913)
Vein.....	18-20°C.	11-17	50	Glass test tubes	Pauwen, Roskam and Swalm (1942)
Vein.....	37°C.	7.3-15.6 15.7-42.9	40 56	Glass test tubes Paraffin-coated tubes	Tocantins (1946)
Vein.....	Room temperature	3.5-14.3	64	Lee and White method, glass test tubes	Aggeler and co-workers (1946)

NORMS FOR CLOT RETRACTION

Two methods of measuring clot retraction are in general use:

1. The amount of serum extruded from the clot at a fixed period of time after coagulation is completed.

*Norms for clot retraction by this method are: adults (both sexes), 47.5 to 61.9 per cent (2 times the standard deviation) of the entire volume of the clot expressed as serum in one hour.*<sup>15</sup>

The amount of serum expressed from the clot is influenced by the red cell content of the clot. To correct for this variation, the amount of serum extruded from the clot may be stated in terms of the percentage of the expected serum volume, as calculated from a hematocrit determination. With this correction and by a method similar to Macfarlane's and a two hour period of observation, the following figures were obtained: Adults (both sexes), 62 to 94 per cent of the total serum volume of the clot (2 times the standard deviation) (Fig. 26).

2. The minimum time required for the clot to begin to retract after it is formed is (both sexes):

- 30 to 60 minutes<sup>21</sup>
- 60 minutes<sup>18</sup>
- 10 to 15 minutes (cutaneous blood)<sup>2</sup>

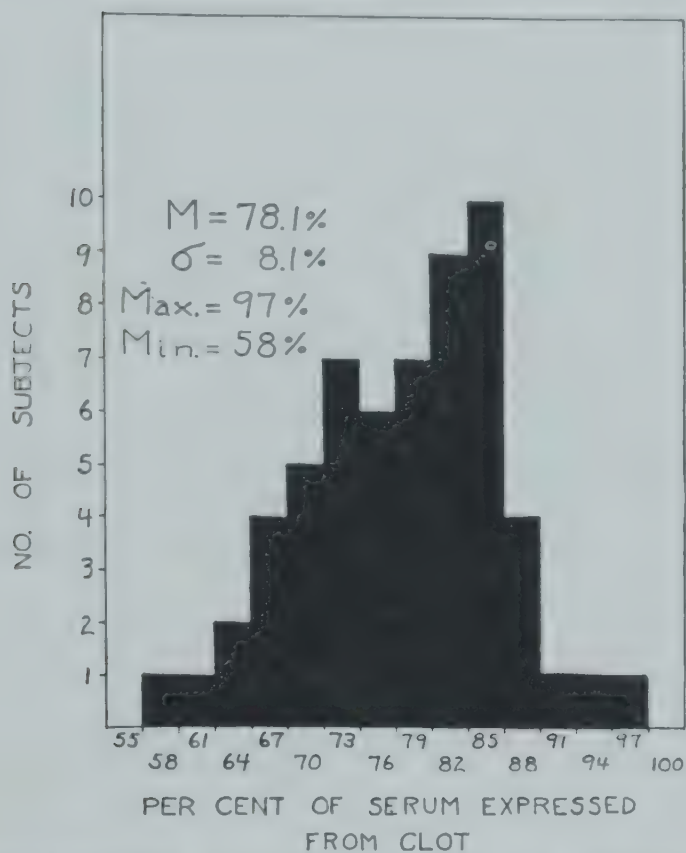


Fig. 26. Frequency histogram for clot retraction from 1 cc. of venous blood in a paraffin tube at 38°C., 2 hours after clot formed (59 adults). (Tocantins, L. M.: M. Clin. North America, vol. 30.)

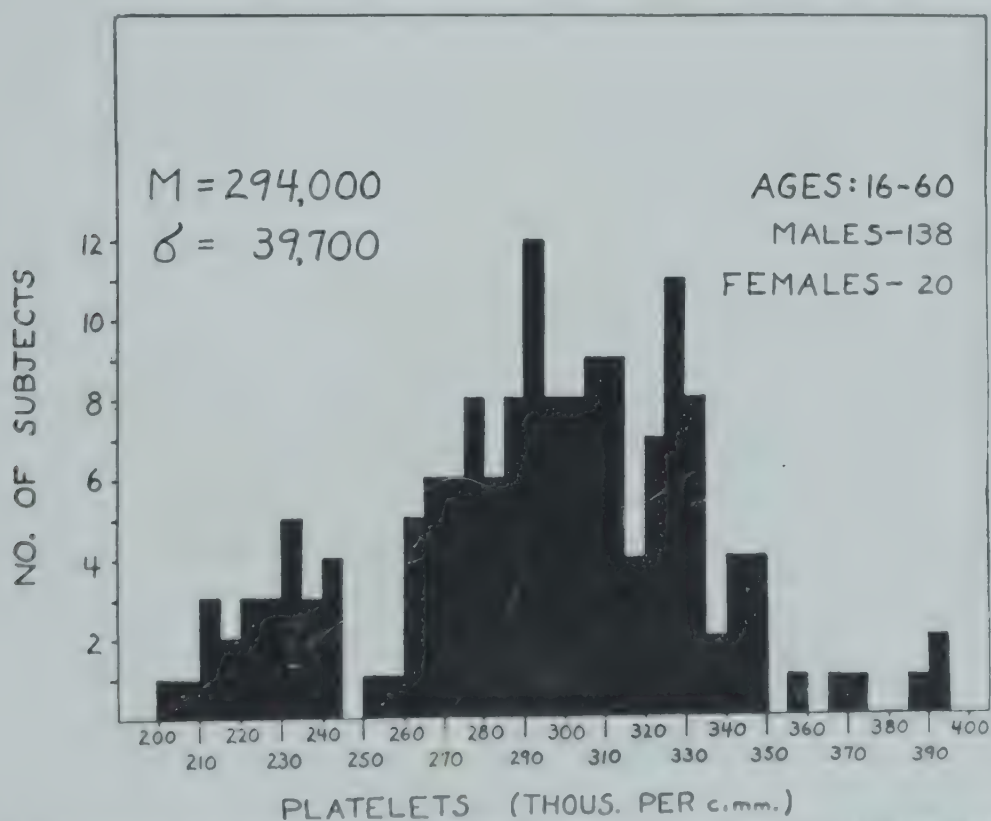


Fig. 27. Frequency histogram for the number of platelets in venous blood of 158 adults. (Kristenson, 1924.)

## PLATELETS

NUMBER. The enumeration of blood platelets has been made in cutaneous and venous blood by the direct and indirect methods. Norms for the number of platelets in cutaneous blood in adults (both sexes) are:

500,000 to 900,000 (indirect method)<sup>4</sup>  
 133,000 to 367,000 (direct method)<sup>23</sup>  
 273,000 to 545,000 (direct method)<sup>1</sup>

Norms for platelets in venous blood in adults are:

Men, 204,000 to 395,000 (direct method)<sup>12</sup>  
 88,000 to 532,000 (direct method)<sup>23</sup>  
 Women, 214,000 to 360,000 (direct method)<sup>12</sup>

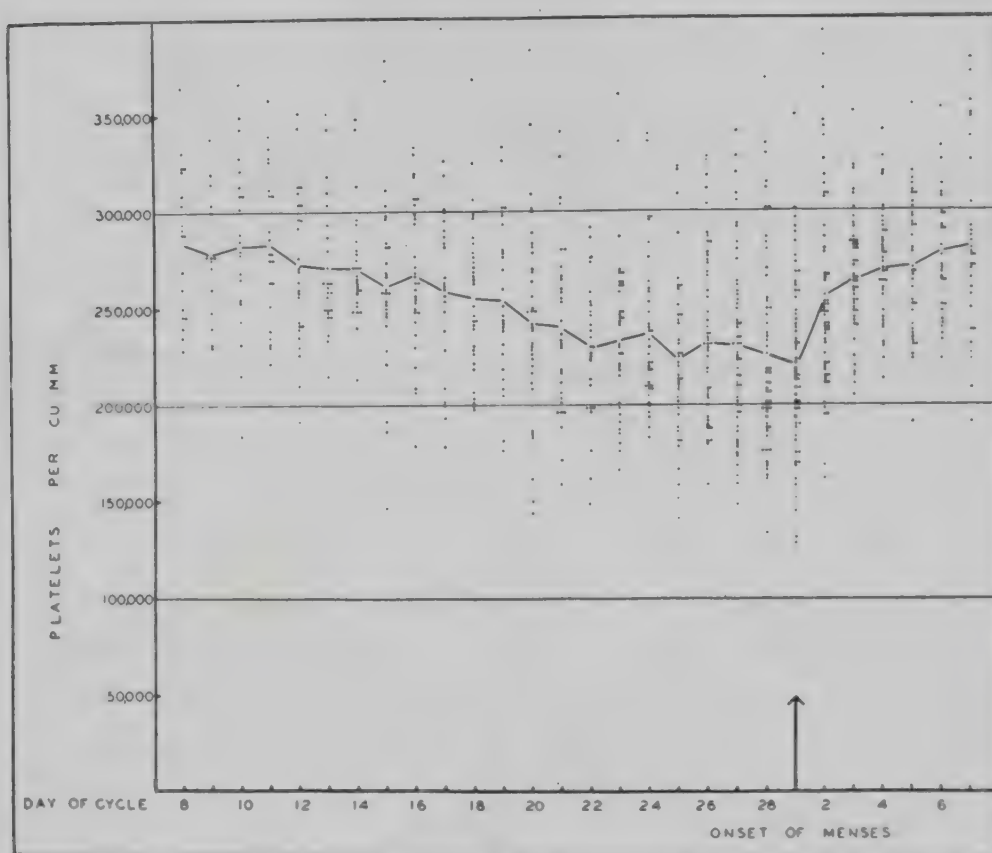


Fig. 28. Blood platelet counts during 82 menstrual cycles in 13 normal women. (Pohle, F. J.: *Am. J. M. Sc.*, vol. 197.)

The number of platelets is about 15 per cent higher in venous than in cutaneous blood, and about 12 per cent higher in arterial than in venous blood. There is a progressive decrease in the platelet count during the fourteen days before menstruation, and a rapid increase soon after the onset of the menses (see Fig. 28).<sup>20</sup>

After sixty years of age the number of platelets is usually significantly lower than in younger persons. Posture, altitude, physical exercise and the environmental temperature influence the number and distribution of platelets.

VOLUME. The average volume per cent of platelets in the blood is 0.49 for both sexes (range, 0.35 to 0.56).<sup>26</sup>

The mean volume of platelets for both sexes is: 5 cubic microns: range, 5 to 75 cubic microns<sup>2</sup> (Horwitz),<sup>8</sup> 10 to 12 cubic microns<sup>3</sup> (Tocantins).<sup>20</sup>

DIAMETER. The diameter (long) of platelets in terms of per cent distribution in the blood is:

13 to 18 per cent = 1.8 microns  
72 per cent = 2.2 microns  
9 to 10 per cent = 3.6 microns or larger

### NORMS FOR BLOOD PROTHROMBIN

Prothrombin activity has been measured in plasma to which an anti-coagulant (sodium citrate or oxalate) has been added, and in whole blood without anticoagulants.

TABLE 31

PROTHROMBIN TIME BY THE ONE-STAGE METHOD (QUICK) IN NORMAL ADULTS OF BOTH SEXES

Test Material	Type of Thromboplastin	Number of Subjects	Mean Prothrombin Time	Range	Remarks	Author
Whole blood . . . . .	Rabbit brain	..	20 secs.	16-24 secs.	....	Kato and Poncher (1940)
Whole blood . . . . .	Rabbit brain	..	..	15-20 secs.	....	Quick (1942)
Plasma . . . . .	Rabbit brain	..	..	11-12.5 secs.	....	Quick (1938)
Whole blood . . . . .	Beef lung	43	43.1 secs.	29.7-56.5 (2 × S.D.) secs.	1 ml. blood +0.1 ml. thromboplastin	Tocantins (1946)
Plasma . . . . .	Rabbit brain	..	..	18-22 secs.	....	Butt and Snell (1941)
Plasma . . . . .	Rabbit brain	85	10 secs.	..	....	Pohle and Stewart (1939)
Plasma . . . . .	Rabbit brain	35	17.8 secs.	13.8-21.8 secs. (2 × S.D.)	Ages 20-81, both sexes	Cotlove and Vorzimer (1946)
Plasma . . . . .	Rabbit brain	3	19.4 secs.	17.5-21.2 secs. (2 × S.D.)	57 determinations	Hause and Tocantins (1941)
Plasma . . . . .	Russell viper venom	26	20.7 secs.	16.1-25.3 secs. (2 × S.D.)	..	Page, DeBeer and Orr (1941)
Whole blood . . . . .	Rabbit brain or lung	..	..	11-12.5*	Glass slide	Hoffman and Custer (1942)

\* Personal communication.

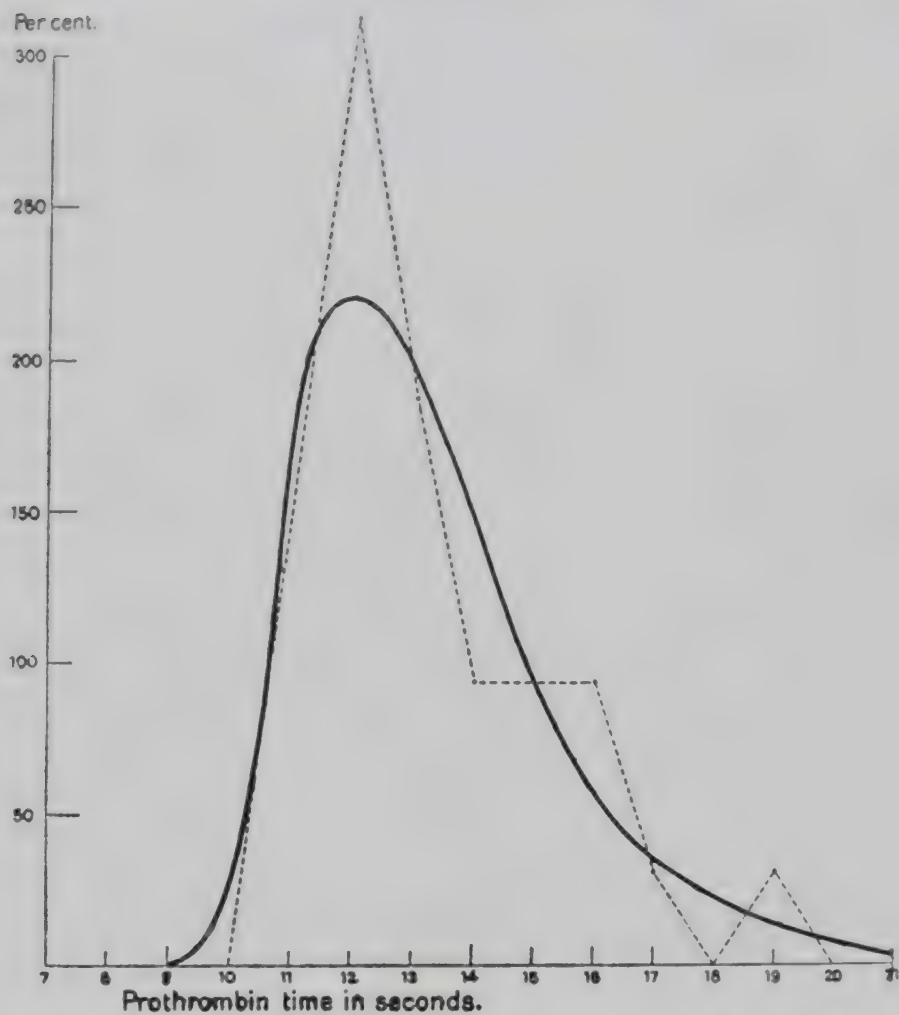


Fig. 29. Frequency distribution of prothrombin time. (Nygaard, K. K.: Hemorrhagic Diseases, C. V. Mosby Company.)

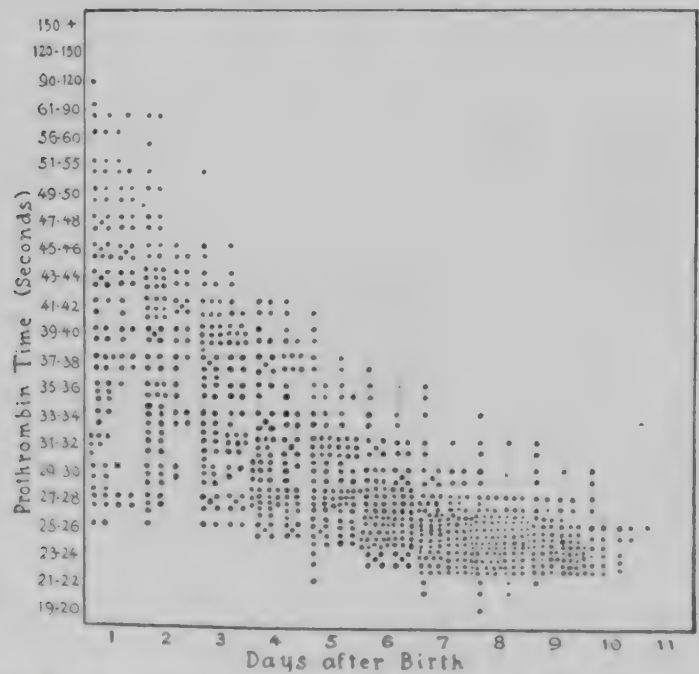


Fig. 30. Distribution of 894 tests of prothrombin time of the blood of 100 normal infants from birth to the 11th day of life. Kato, K., and Poncher, H. G.: J.A.M.A., vol. 114.

**ONE-STAGE METHOD.** This consists in measuring the clotting time after adding a concentrated solution of thromboplastin (usually rabbit brain extract) to the recalcified oxalated or citrated plasma. The time required for clotting of the plasma is largely a function of its prothrombin content. By comparing this time with that of normal plasma, similarly treated, it is possible to express prothrombin activity in terms of per cent of normal. Since the potency of the thromboplastin has been known to vary, it is necessary to standardize it by testing its action on pooled plasma. The prothrombin activity of blood may be estimated by adding a given amount of thromboplastin directly to a measured amount of blood and noting the clotting time. By comparing that time with that observed in normal blood, an approximate estimate of the prothrombin activity of the unknown may be obtained.

Table 31 lists the prothrombin times obtained by the one-stage method in citrated and venous blood and in venous plasma with different thromboplastic agents. The variation in the results is due principally to differences in activity of the reagents used. It follows, therefore, that the times given in the table represent the norms only for the particular set of reagents and conditions used by each worker. A given prothrombin time may be considered abnormal only in reference to the times obtained in the blood or plasma of normal subjects examined with the same method and reagents used with the unknown sample (Figs. 29 and 30).

**TWO-STAGE METHOD.** Concentrated thromboplastin is added to the defibrinated, oxalated, diluted plasma, time is allowed for the full conversion of all the prothrombin, and then a solution of fibrinogen is added. Prothrombin activity is expressed in units, a unit being arbitrarily defined as the amount of prothrombin which, when completely converted into thrombin, clots a solution of fibrinogen in fifteen seconds.<sup>22, 27</sup>

*Norms for adults (both sexes) are 270 to 325 units per milliliter of plasma.<sup>22</sup>*

## ANTITHROMBIN

Plasma and serum have the property of reducing or destroying the clotting power of solutions of thrombin. This antithrombin activity of plasma and serum has been measured against a thrombin solution of standard potency. One unit of antithrombin is defined as that amount which will inactivate 1 unit of thrombin in four minutes at 28° C.<sup>28</sup> *The values for antithrombin in normal plasma or serum are (both sexes) 74 to 115 units.<sup>28</sup>*

## FIBRINOGEN

Fibrinogen is the plasma protein which, when converted to fibrin by thrombin, forms the framework of the clot. Normal values for plasma fibrinogen are given on page 109.

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# Chapter 9

## BLOOD GROUPS

### MAJOR GROUPS

ON THE BASIS of agglutination reactions between the blood cells of certain persons and the serum of others, human blood has been divided into four groups. The existence of the four groups depends upon the presence or absence of two agglutinogens, A and B, in the red corpuscles and two agglutinins, *a* (or anti-A) and *b* (or anti-B), in the serum or the plasma. Table 32 shows the blood groups and their equivalents in the old (no longer generally accepted) Jansky and Moss nomenclatures.

TABLE 32  
CLASSIFICATION OF BLOOD GROUPS

<i>International Standard Nomenclature</i>	<i>Agglutinogen (Erythrocytes)</i>	<i>Isoagglutinins (Serum or Plasma)</i>	<i>Jansky Nomenclature</i>	<i>Moss Nomenclature</i>
O.....	....	a and b	I	IV
A.....	A	b	II	II
B.....	B	a	III	III
A B.....	A B	....	IV	I

When the red cells of each of the four groups are mixed with the serum of each of the others, they may or may not be agglutinated, as shown in Table 33.

TABLE 33  
CROSS AGGLUTINATION OF THE MAJOR BLOOD GROUPS

<i>Red Cells of Group</i>	<i>Serum of Group</i>			
	<i>O (Anti-A and Anti-B)</i>	<i>A (Anti-B)</i>	<i>B (Anti-A)</i>	<i>A B (—)</i>
O.....	—	—	—	—
A.....	+	—	+	—
B.....	+	+	—	—
A B.....	+	+	+	—

+ = Agglutination.                      — = No agglutination.

The blood group of any person may be determined by testing the reaction of his red cells to the serums of known A and B bloods. If the cells are not

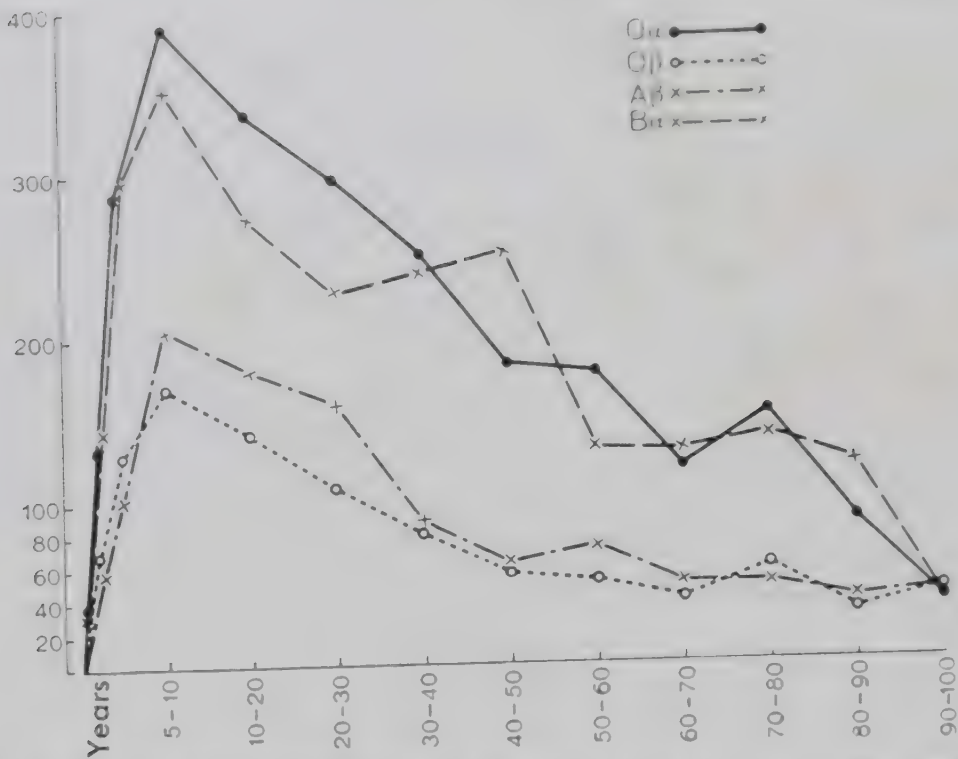


Fig. 31. Development of the isoagglutinins (agglutinin titers at various ages . (Thomsen, O., and Kettel, K.: Ztschr. f. Immunitätsforsch. u. exper Therap., vol. 63.)

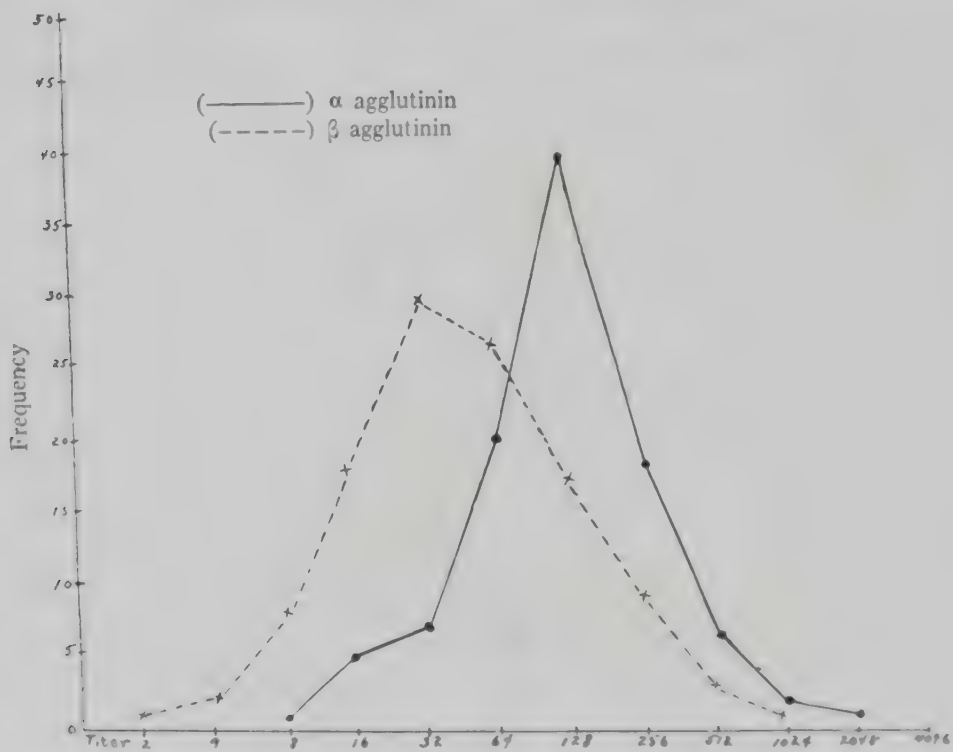


Fig. 32. Variation of isoagglutinin titer among normal adults. (Traced from data of Kettel). (Wiener, A. S.: Blood Groups and Blood Transfusions, Charles C Thomas.)

agglutinated by either serum, the blood is of group O; if agglutinated by the serum of group B only, the blood is of group A; if agglutinated by the serum of group A only, the blood is of group B; if agglutinated by both serums, the

blood is of group AB. Conversely, if serum alone is available, the group to which it belongs may be determined by testing its effect on suspensions of known A or B red cells.

### SUBGROUPS

There are two types of agglutinin,  $A_1$  and  $A_2$ , which react differently from each other to the same anti-A serum. The  $A_2$  agglutinin is a weak receptor and requires anti-A serums of high titer for its detection. The subgroups classified on the basis of the difference between  $A_1$  and  $A_2$  are, therefore,  $A_1$ ,  $A_2$ ,  $A_1B$  and  $A_2B$ .

The isoagglutination reaction is best demonstrated at temperatures of 0° C. or below and is speeded up by throwing the cells together as by centrifugation. The proportion between the cells and serum and the agglutinin titer of the serum are other important factors influencing the reaction.

The agglutinogens are not fully developed at birth. The red blood cells of the newborn infant have only about 20 per cent of the sensitivity to agglutination of adult blood. Whatever isoagglutinins are present at birth (only about one-half of all newborn infants have them) are probably derived from the mother through the placenta. They usually disappear during the first ten days of life and are then replaced by the infant's own. The isoagglutinins increase in titer up to the age of puberty, after which they gradually diminish. Figure 31 shows the variation in the titers of the anti-A and anti-B agglutinins in the blood of adult persons. The anti-A agglutinin has an average titer higher than that of the anti-B agglutinin at all ages (Fig. 32).

### ISOHEMOLYSIS

When fresh serum is used in grouping tests, hemolysis as well as agglutination of the red cells is often observed. This depends on the presence of complement and corresponds in its specificity to that of the isoagglutinins of the serum. Isohemolysis is probably due to the same substances as isoagglutination and is especially observed with serums of high titer.

### AUTOAGGLUTINATION

This is the agglutination of normal red cells by a person's own serum or plasma because of the presence of an agglutinin in the serum and a corresponding agglutinin in the red cells. The reaction occurs only in tests made at low temperatures and operates regardless of the blood groups. It differs from isoagglutination in its greater sensitivity to temperature. The reaction can generally be reversed by warming the mixture to body temperature, and can be made to reappear by chilling.

### PSEUDOAGGLUTINATION

This is the aggregation of red cells in rouleaux or coinlike piles. If the rouleaux are large they may resemble true agglutination. Table 34 shows the differentiating points between isoagglutination, autoagglutination and pseudoagglutination.

BLOOD CELLULAR ELEMENTS

TABLE 34

DIFFERENTIATION OF PSEUDOAGGLUTINATION, AUTOAGGLUTINATION AND ISOAGGLUTINATION

(Modified after Landsteiner by Wiener)

	<i>Pseudoagglutination</i>	<i>Autoagglutination</i>	<i>Isoagglutination</i>
Absorption of active principle . . . . .	Not absorbable	Absorbable	Absorbable
Effect of temperature on tests . . . . .	Not weaker; rather stronger at 37°C. than at lower temperature	Occurs as a rule only at low temperatures	Little affected by changes of temperature from 0°-37°C.
Effect of dilution . . . . .	Inactivated by slight dilution	Stands considerable dilution	Stands considerable dilution
Specificity . . . . .	Nonspecific	Nonspecific	Group specific

DISTRIBUTION OF BLOOD GROUPS

The distribution of the blood groups in man varies according to race. Table 35 gives the percentage distribution of the principal groups and subgroups in residents of the United States.

TABLE 35

DISTRIBUTION OF MAJOR BLOOD GROUPS

<i>Population</i>	<i>Groups and Subgroups</i>					
	<i>O</i>	<i>A<sub>1</sub></i>	<i>A<sub>2</sub></i>	<i>B</i>	<i>A<sub>1</sub>B</i>	<i>A<sub>2</sub>B</i>
American Indians . . . . .	73.3	25.8	0	0.8	0	0
Whites (U.S.A.) . . . . .	41.7	29.0	8.9	13.9	5.2	1.4
Negroes (U.S.A.) . . . . .	48.1	19.6	6.8	22.8	1.6	1.1

For distribution of groups among other races and in other countries of the world, consult Wiener, A. S.: Blood Groups and Blood Transfusion, 3rd ed., Tables 67 and 73.

Besides the agglutinogens just mentioned, it has been shown that human red cells may contain, independent of the standard blood groups, the agglutinogens M, N, P, Q or Rh, singly or in combination.

M AND N AGGLUTINOGENS

Human erythrocytes may contain either the M agglutinin alone or the N agglutinin alone, or the MN agglutinogens together. These properties are present independent of other agglutinogens. Table 36 gives the distribution of the M and N agglutinogens in the population of the United States.

TABLE 36  
DISTRIBUTION OF M AND N AGGLUTINOGENS

Population	Percent of Types		
	M	N	MN
Whites U.S.A.	26.1	20.3	53.6
Negroes U.S.A.	28.4	21.9	49.6
Indians U.S.A.	60.0	4.8	35.1

Rh AGGLUTINOGEN

This agglutinin has been called Rh because it was first discovered in the Rhesus monkey. On the basis of reactions with specific antisera, eight types (including Rh negative) are now recognized.

TABLE 37  
VARIETIES OF RH AGGLUTINOGEN  
(Modified from Wiener, 1944)<sup>8</sup>

Types	Frequency in White Persons (U.S.A.) (Per Cent)	Reaction with Anti- Rh <sub>0</sub> Agglutinin
Rh <sub>0</sub>	2.5	+
Rh <sub>1</sub>	53.6	+
Rh <sub>2</sub>	13.4	+
Rh <sub>1</sub> Rh <sub>2</sub>	16.8	+
Rh'	0.8	-
Rh''	0.5	-
Rh' Rh''		-
Rh negative	12.4	-

For clinical purposes it is sufficient to remember that the important types are Rh<sub>0</sub>, Rh<sub>1</sub>, Rh<sub>1</sub>Rh<sub>2</sub> and Rh negative, and that the anti-Rh<sub>0</sub> agglutinin will be effective against the red cells of about 85 per cent (86.3 per cent in Table 37) of white persons. Bloods of Rh' and Rh'' group do not react with the standard anti-Rh<sub>0</sub> agglutinin; special antisera are required for their demonstration.

The original Rh nomenclature, developed to fit the immediate needs of investigators for a designation for newly found factors, has become cumbersome. English investigators<sup>2</sup> have proposed using the letters C, D and E to designate the three principal Rh and Hr antigens as follows:

American classification:	Rh'	Rh <sub>0</sub>	Rh''	Hr'	Hr <sub>0</sub>	Hr''
English classification:	C	D	E	c	d	e

Each Rh type has a complex antigenic structure which usually includes combinations of these three factors. Table 38 shows the various Rh groups and Rh antisera with their counterparts in the English classification. Clinically, the most important serum is the anti-Rh<sub>0</sub> serum, which agglutinates

about 85 per cent of red cells of white human beings. This is the serum referred to by the British as the anti-D serum (see Table 38).

TABLE 38

REACTIONS BETWEEN THE SEVERAL VARIETIES OF HUMAN RH ANTISERUMS AND THE Rh FACTORS OF HUMAN RED CELLS [ENGLISH AND EQUIVALENT AMERICAN DESIGNATIONS]  
(Modified from Cappell, 1946; Belding and Ross, 1947)

Human Rh Antisera		"Rh Positive" Types of Red Cells				"Rh Negative" Types of Red Cells			
American Nomenclature	English Nomenclature	American Classification				American Classification			
		Rh <sub>0</sub>	Rh <sub>1</sub>	Rh' <sub>1</sub>	Rh <sub>2</sub>	Rh'' <sub>2</sub>	Rh-Rh <sub>2</sub>	Rh'-Rh'' <sub>2</sub>	rh rh' rh'' rh <sub>1</sub> rh'' <sub>1</sub>
		English Classification				English Classification			
		cDe	CDe	cDE	CDE	cde	Cde	cdE	CdE
Anti-Rh <sup>0</sup>	Anti-D	+	+	+	+	-	-	-	-
Anti-Rh'	Anti-C	-	+	-	+	-	+	-	+
Anti-Rh''	Anti-E	-	-	+	+	-	-	+	+
Anti-Rh <sub>1</sub>	Anti-C&D	+	+	+	+	-	+	-	+
Anti-Rh <sub>2</sub>	Anti-D&E	+	+	+	+	-	-	+	+
Anti-Hr'	Anti-c	+	-	+	-	+	-	+	-
Anti-Hr''	Anti-e	+	+	-	-	+	+	-	-
Anti-Hr <sub>0</sub>	Anti-d	-	-	-	-	+	+	+	+

Hr FACTOR

The characteristic feature of Rh negative blood is its failure to be agglutinated by anti-Rh serums. Such Rh negative red cells have, however, an agglutininogen which renders them agglutinable by certain serums. This agglutininogen seems to be reciprocally related to Rh and for this reason has been named Hr. Anti-Hr serum agglutinates not only all Rh negative bloods, but also Rh positive red cells, the Rh agglutinogens of which have been determined by the genes Rh<sub>0</sub>, Rh<sub>1</sub>, Rh'' and rh, but not those determined by the genes Rh<sub>2</sub> and Rh'. The standard Hr factor seems to be related to agglutininogen Rh' as agglutininogen M is related to N. For this reason the standard Hr agglutininogen has been designated Hr'. The three varieties of Hr agglutininogen are therefore Hr', Hr'' and Hr<sub>0</sub>. These are reciprocals, respectively, of Rh', Rh'' and Rh<sub>0</sub>.

HEREDITY OF THE BLOOD GROUPS AND TYPES

The agglutinogens A, B, M and N are inherited as mendelian dominants. Tables 39 and 40 show the relations of parentage to the major blood groups and the M and N agglutinogen. Blood grouping and testing for agglutinogens have been applied in medicolegal cases for the exclusion of parentage. At first only the classic blood grouping tests were applied, but since 1930, tests for M and N agglutinogens have been included.

TABLE 39  
MAJOR BLOOD GROUPS IN RELATION TO PARENTAGE

<i>Groups of Parents</i>	<i>Groups of Children Possible (Bernstein)</i>	<i>Groups of Children Not Possible</i>
O × O.....	O	A, B, AB
O × A.....	O, A	B, AB
O × B.....	O, B	A, AB
O × AB.....	A, B	O, AB
A × A.....	O, A	B, AB
A × B.....	O, A, B, AB	.....
A × AB.....	A, B, AB	O
B × B.....	O, B	A, AB
B × AB.....	A, B, AB	O
AB × AB.....	A, B, AB	O

TABLE 40  
AGGLUTINOGENS M AND N IN RELATION TO PARENTAGE

<i>Groups of Parents</i>	<i>Groups of Children Possible</i>	<i>Groups of Children Not Possible</i>
MN × MN.....	MN, M, N	..
MN × N.....	MN, N	M
MN × M.....	MN, M	N
M × N.....	MN	M, N
M × M.....	M	MN, N
N × N.....	N	MN, M

The Rh types are transmitted by at least six allelic genes, rh, Rh', Rh'', Rh<sub>1</sub>, and Rh<sub>2</sub>.<sup>7</sup> The Rh agglutinogen is transmitted as a mendelian dominant. Rh negative persons are all homozygous (rh rh), while Rh positive persons could be either homozygous (Rh Rh) or heterozygous (Rh rh). Inheritance of the types is neither sex linked nor sex influenced. Tables 41 and 42 list the types of the blood of children derived from various matings.

TABLE 41  
RH AGGLUTINOGEN IN RELATION TO PARENTAGE

<i>Groups of Parents</i>	<i>Groups of Children Possible</i>	<i>Groups of Children Not Possible</i>
Rh+ × Rh+.....	Rh+, Rh-	.....
Rh+ × Rh-.....	Rh+, Rh-	.....
Rh- × Rh-.....	Rh-	Rh+

TABLE 42

HEREDITY OF RH BLOOD TYPES: SUMMARY OF RESULTS OF 300 FAMILIES  
WITH 620 CHILDREN  
(Wiener, et al., 1946)<sup>9</sup>

Mating	Number of Families	Number of Children of Types							Total
		rh	Rh <sub>1</sub>	Rh <sub>2</sub>	Rh <sub>1</sub> Rh <sub>2</sub>	Rh <sub>0</sub>	Rh'	Rh''	
rh × rh	7	18	0	0	0	0	0	0	18
rh × Rh <sub>1</sub>	82	34	122	0	0	9	0	0	165
rh × Rh <sub>2</sub>	23	11	0	30	0	1	0	0	42
rh × Rh <sub>1</sub> Rh <sub>2</sub>	32	(1)	30	29	0	0	0	0	60
rh × Rh <sub>0</sub>	4	3	0	0	0	4	0	0	7
rh × Rh'	2	1	0	(1)	0	0	1	0	3
rh × Rh''	1	1	0	0	0	0	0	5	6
Rh <sub>1</sub> × Rh <sub>1</sub>	44	7	86	0	0	4	1	0	98
Rh <sub>1</sub> × Rh <sub>2</sub>	28	10	20	9	18	0	2	0	59
Rh <sub>1</sub> × Rh <sub>1</sub> Rh <sub>2</sub>	35	0	52	10	30	0	0	0	92
Rh <sub>1</sub> × Rh <sub>0</sub>	2	2	0	0	0	0	0	0	2
Rh <sub>1</sub> × Rh'	7	0	5	0	0	0	2	0	7
Rh <sub>1</sub> × Rh''	4	1	2	0	3	0	0	0	6
Rh <sub>2</sub> × Rh <sub>2</sub>	2	1	0	4	0	0	0	0	5
Rh <sub>2</sub> × Rh <sub>1</sub> Rh <sub>2</sub>	12	0	6	12	8	0	0	0	26
Rh <sub>2</sub> × Rh <sub>0</sub>	2	0	0	1	0	4	0	0	5
Rh <sub>1</sub> × Rh'	1	0	0	1	0	0	0	0	1
Rh <sub>1</sub> Rh <sub>2</sub> × Rh <sub>1</sub> Rh <sub>2</sub>	6	0	3	2	4	0	0	0	9
Rh <sub>1</sub> Rh <sub>2</sub> × Rh <sub>0</sub>	3	0	2	1	0	0	0	0	3
Rh <sub>1</sub> Rh <sub>2</sub> × Rh'	2	0	1	1	2	0	0	0	4
Rh <sub>0</sub> × Rh'	1	0	0	0	0	1	1	0	2
Totals	300	90	329	101	65	23	7	5	620

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## Chapter 10

### THE BONE MARROW

ALL THE tissues of the body the bone marrow presents perhaps the greatest difficulty in establishing a norm, owing to its instability and to errors and variations in the means of study by different investigators. Nonetheless, certain data of reasonable accuracy may be presented.

Although it is widely dispersed, the bone marrow must be regarded as a single organ, one of the largest in the body. Its volume has been estimated as ranging from 67 to 91 ml. at birth and from 1320 to 4192 ml. in adults. The total marrow space is greater in men than in women, and the aging process in man increases the volume in elderly persons.

At birth the marrow cavity of all bones is completely filled with red (blood-forming) marrow. In early infancy, however, a few fat cells appear in bones of the extremities, and over the succeeding years a gradual regression of hematopoietic tissue follows, with a concomitant fat replacement of the marrow spaces. Figure 34 indicates the general trend of this process. One notes that by young adult life the two long bones sampled (tibia and femur) are almost completely fatty, whereas the three flat bones (rib, sternum and vertebrae) retain their blood-forming function in varying degrees throughout life. Beyond the age of twenty years red marrow is limited to the vertebrae, sternum, ribs, clavicles, scapulae and bones of the skull and pelvis, although there are also small foci of red marrow at the proximal ends of the femora and humeri.

The disposition of fat follows the growth of marrow spaces beyond the body requirements for blood-forming tissue. Temperature is probably the main factor in determining the sites of marrow involution, the temperature of the extremities being appreciably lower than that of the torso and head.

With the exception of the blood itself, the bone marrow is the most labile tissue in the body. Fat may be displaced by spreading hematopoietic tissue in an extraordinarily short time; a transition has been observed from completely fatty marrow to solidly cellular marrow within two days under experimental conditions.<sup>2</sup> The process spreads distalward, so that the bones of the forearms, legs, hands and feet are late participants and undergo hyperplasia only as a result of excessive stimuli.

#### STROMA

The stroma of the marrow is formed by a delicate framework of argyrol-philic reticular fibers to which the reticulum cells are closely applied. The fibers are attached to the endosteum and are connected with vascular walls.

#### NERVES

These are largely sympathetic trunks which accompany the larger blood vessels. Relatively few sensory fibers are present, and ganglion cells have not been demonstrated.



## BLOOD SUPPLY

There are apparently no lymphatic channels in the marrow.

The nutrient vessels to the marrow are large, and are unusual in that they break up into a vast sinusoidal network almost immediately on entering the bone. The sinusoids are walled for the most part by a single layer of endo-

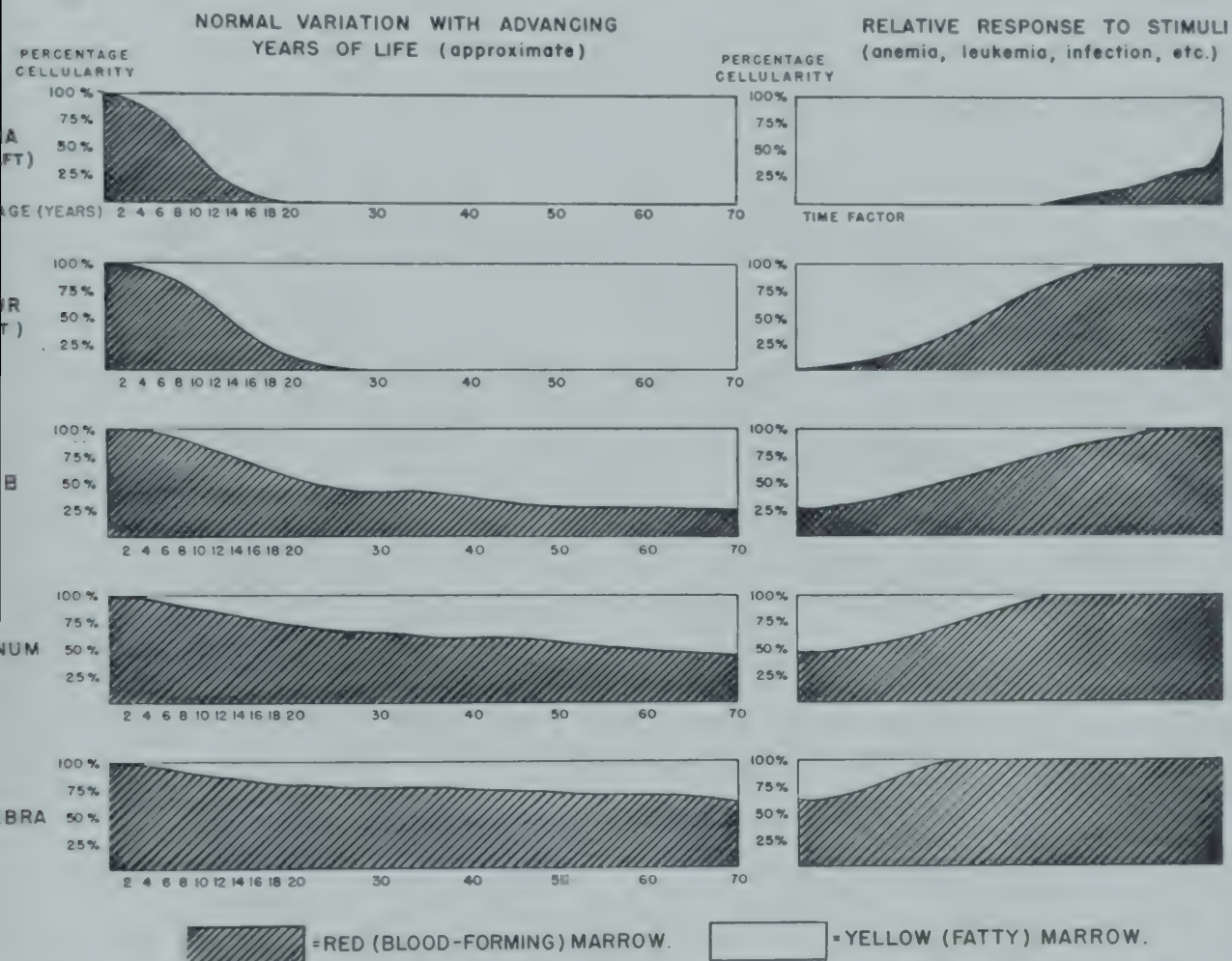


Fig. 34. Cellularity of various bones at different ages. The first section represents the regression of hematopoietic tissue and its replacement by fatty marrow in representative long and flat bones with advancing age. It is based on a series of autopsies on persons who died from causes unlikely to have affected the blood-forming organs. The second section illustrates the relative response of these bones to hematopoietic stimuli, such as anemia, leukemia or infection, regardless of age. (Custer, R. P.: Atlas of the Blood and Bone Marrow.

helium, but have an appreciably larger potential caliber than do capillaries of other tissues. The volume of the combined lumina is such that the rigid bone casing makes it impossible for all to attain their maximum caliber at the same time. Thus many of the blood channels are reduced to fine capillary size or are closed to the circulation altogether.

## CYTOLOGIC PATTERN

There is considerable variation in the cellular components of the bone marrow in presumably normal persons, and even from bone to bone in the same person. In general, the hematopoietic tissue occupies the areas between fat cells and open blood channels, the granulocyte progenitors forming a diffuse

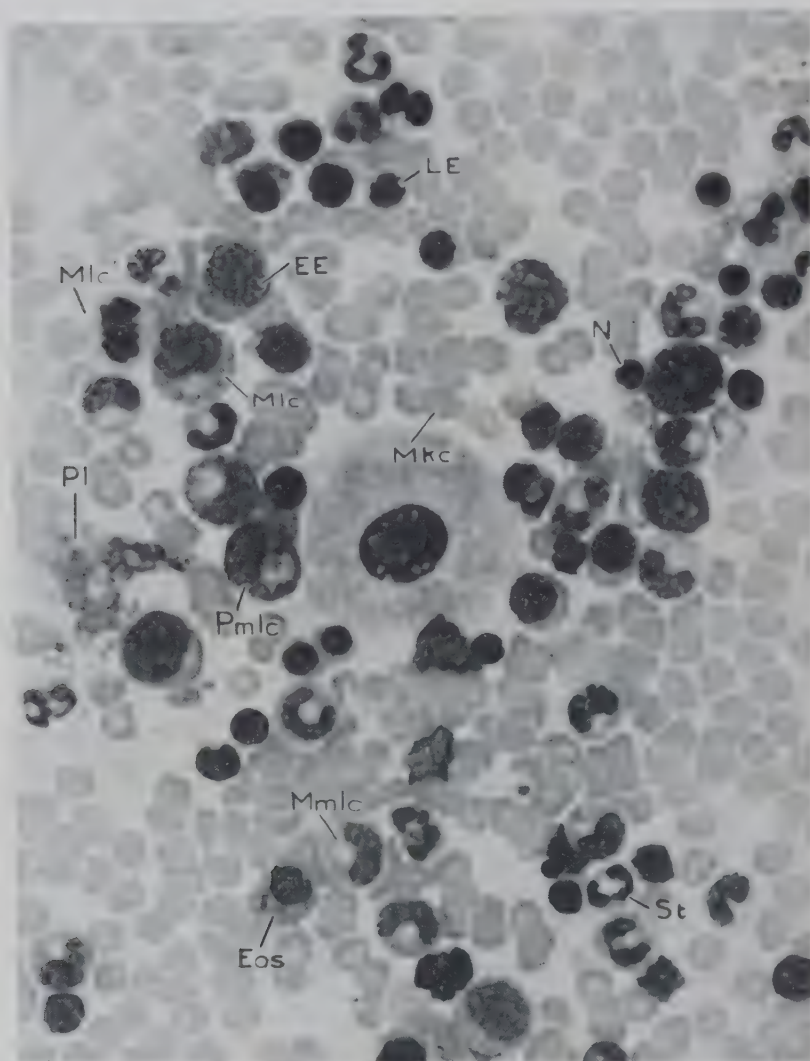


Fig. 35. Normal sternal bone marrow aspirate. Photomicrograph of a relatively thin part of the marrow smear shows the usual dispersion of cells, with granulocytes predominating, the erythro-myeloid ratio being roughly 1:2. *EE*, Early erythroblast; *LE*, late erythroblast; *N*, normoblast; *Pmlc*, promyelocyte; *Mlc*, myelocyte; *Mlc'*, myelocyte in mitosis; *Mmlc*, metamyelocyte, *St*, stab; *Eos*, eosinophilic myelocyte; *Mkc*, megakaryocyte (uninuclear; these cells characteristically have multilobate nuclei); *Pl*, platelets. There are also a few lymphocytes intermingled, derived from admixed peripheral blood. Custer, R. P.: Atlas of the Blood and Bone Marrow.

background and the nucleated red forms tending to aggregate in clumps (Fig. 35). Megakaryocytes are sparsely distributed and usually lie in juxtaposition to sinusoids; often, however, this relationship is not apparent unless the marrow is studied by serial sections. Cells of the reticuloendothelial system are inconspicuous.

## ERYTHRO-MYELOID RATIO (E:M)

The erythro-myeloid ratio may vary from 1:2 to 1:6 (it has been recorded great as 1:10, but this seems rather too high to be regarded as normal). The erythrocyte and granulocyte series comprise 90 to 95 per cent of the marrow cells, exclusive of fat cells.<sup>2</sup>

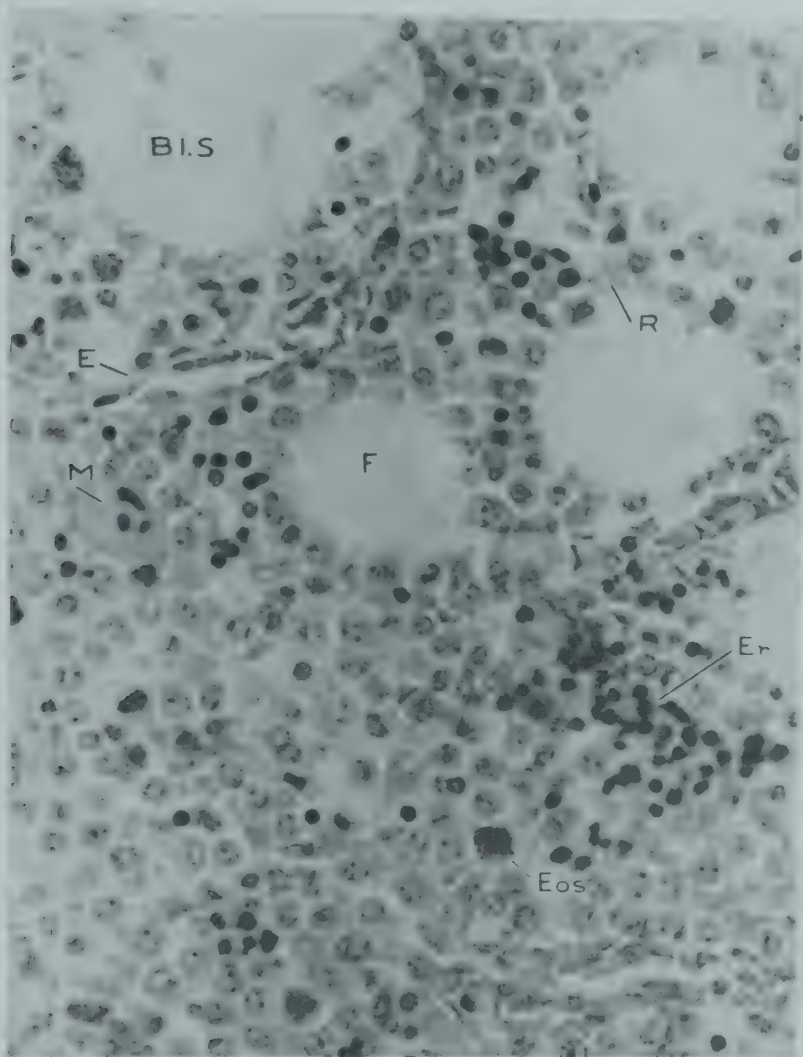


Fig. 36. Normal bone marrow. The sternal marrow from a woman 22 years of age, who had a brain tumor, but was otherwise healthy, represents the normal contents of this bone marrow at this age. Somewhat less than a quarter of the space is occupied by fat cells (F) and large, pale-walled blood sinuses (B.L.S.). The large, pale-staining cells with vesicular nuclei belong to the neutrophile series, while the eosinophils (Eos) are conspicuous by their coarse granulation. Reticulum cells (R) are scattered throughout the interstices, and blood channels are lined for the most part by specialized sinus endothelial cells (E). Megakaryocytes (M) are sparsely distributed. Red blood cell formation tends to be focalized (Er), the majority of cells being in the erythroblastic and normoblastic stages. (Custer, R. P.: Atlas of the Blood and Bone Marrow.)

## DIFFERENTIAL COUNT

It is difficult to present a *normal differential count* as a standard for comparison. Methods of study differ far too widely, and counts on aspirated and centrifuged marrow from the same person seldom correspond closely. The value

of differential counts, unless performed on meticulously prepared marrow sections and carried out according to a standard technic, is questionable. When the deviations from normal exceed the variations shown in the several tables, it seldom requires a count to make them apparent.

Tables 43, 44, 45 and 46 give the normal ranges for the various cells in the differential count of bone marrow. With the exception of Table 43, the counts are made from bone marrow aspirated from the sternum of adults. The number of cells tabulated varies from 500 to 1000, and the plan of sampling various parts of the smears is not specified. Counts per cubic millimeter of the nucleated cells of the marrow aspirate, made according to the routine technic for leukocytes, are helpful in estimating the degree of dilution with peripheral blood except in marrow hypoplasia.

TABLE 43  
NORMAL DIFFERENTIAL COUNT OF BONE MARROW  
(Custer)<sup>1</sup>

Cell Type		Range in Per Cent
Undifferentiated cells.....		0.0
Myeloblasts.....		0.0- 3.5
Promyelocytes	Neutrophil.....	0.5 - 9.0
	Eosinophil.....	0.1 - 2.0
	Basophil.....	0.0 - 0.1
Myelocytes	Neutrophil.....	7.0 -34.6
	Eosinophil.....	0.3 - 3.0
	Basophil.....	0.0 - 0.5
Metamyelocytes	Neutrophil.....	14.8 -33.0
	Eosinophil.....	0.3 - 3.7
	Basophil.....	0.0 - 0.3
Segmenters	Neutrophil.....	3.0 -19.8
	Eosinophil.....	0.1 - 3.0
	Basophil.....	0.0 - 1.0
Megaloblasts (Proerythroblasts).....		0.0
Erythroblasts.....		4.2 -18.2
Normoblasts.....		13.3 -23.8
Megakaryoblasts.....		0.0 - 0.25
Megakaryocytes.....		0.05- 1.2
Reticuloendothelial cells.....		0.3 - 2.6
Monocytes.....		0.1 - 3.2
Lymphocytes.....		0.0 -16.8
Plasmocytes.....		0.0 - 1.2

Table 43 gives a fair sample of what may be regarded as the usual finding in healthy adults. The values represent a compilation of counts made from both aspirates and sections of sternal marrow. Some samples were aspirated during life from persons in whom there proved to be no significant alteration in the tissue; others were obtained after accidental death, or from patients dying of conditions such as brain tumor who had normal blood counts. The aspirates obtained during life naturally contained varying amounts of peripheral blood, accounting for the occasionally high lymphocyte count.

Small nodular aggregates of lymphocytes are fairly frequent findings in otherwise normal marrow, especially in the older age group. Their significance, if any, is not known, but they are to be distinguished from the nodular involvement of the marrow seen in chronic lymphocytic leukemia.

TABLE 44  
OBSERVATIONS ON BONE MARROW OF HEALTHY HUMAN ADULTS  
(Vaughan and Brockmyre, 1947)<sup>7</sup>

Determinations	No. of Cases	Range	Mean	Stand-ard Error	Stand-ard Devia-tion	% of Cases within the Range of 6 S.D.	Coeffi-cient of Varia-tion	No. of Cases in Which Cells Appear-ed in Counts
total nucleated cells.....	50	9400-74,000	35,300	2075	14,670	100	41.27	50
proerythroblasts.....	50	0.0- 3.0%	1.33%	0.10	0.70	100	52.95	47
erythrocytes.....	50	2.0-15.5%	8.92%	0.45	3.18	100	35.68	50
myeloid forms.....	50	3.5-17.5%	8.75%	0.44	3.09	100	35.35	50
myeloid forms.....	50	12.0-34.0%	23.92%	0.85	5.98	100	25.01	50
myeloid forms.....	50	6.0-35.5%	18.47%	0.86	6.08	100	32.93	50
mononuclear cells.....	50	0.0- 6.5%	1.86%	0.15	1.03	98	55.36	48
mononuclear cells.....	50	0.0- 1.5%	0.15%	0.05	0.32	...	213.40	11*
lymphocytes.....	50	7.0-34.5%	16.22%	0.79	5.56	98	34.28	50
monocytes.....	50	0.0- 6.0%	2.42%	0.23	1.63	100	67.43	47
plasma cells.....	50	0.0- 1.5%	0.33%	0.06	0.45	...	132.54	22*
reticuloendothelial cells.....	50	0.0- 2.5%	0.25%	0.07	0.47	...	188.64	15*
unidentified cells.....	50	0.0- 0.5%	0.02%	...	...	...	...	2*
integrated cells.....	50	0.0-18.0%	7.85%	0.53	3.74	100	47.69	49
erythroblasts.....	50	1.5-24.0%	9.51%	0.66	4.68	100	49.24	50
reticulocytes%...	50	0.1- 2.8%	0.94%	0.04	0.30	92	31.91	50
megakaryocytes/10 l.p.f. ....	50	0.0-44.0	9.62	1.23	8.73	100	90.78	49

\* These cells were found too infrequently to be significant from a statistical standpoint. Computations were carried out to 3 digits.

TABLE 45

AVERAGE PERIPHERAL BLOOD AND MARROW COUNTS IN INFANTS FIRST 24 HOURS  
AND 1 WEEK LATER)\*(Shapiro and Bassen, 1941)<sup>6</sup>

	All Cases		Females		Males	
	1st 24 Hrs.	Wk. Later	1st 24 Hrs.	Wk. Later	1st 24 Hrs.	Wk. Later
Age in hrs.	11.4	.....	11.3	.....	11.7	.....
Wt. (lbs. and oz.)	7:02	7:05	7:00	7:03	7:12	7:13
Peripheral blood chamber count:						
Hb., %	135.1	120.6	131.6	117.1	140.4	125.7
Hb., gm. per 100 cc.	19.8	17.6	19.3	17.1	20.5	18.3
RBC (millions)	5.5	4.8	5.4	4.7	5.7	5.0
WBC (thousands)	24.0	14.2	24.9	14.1	23.0	14.7
Peripheral blood smear:						
Myelocyte	0.8	0.0	0.9	0.1	0.8	0.0
Nonsegmented	13.5	2.5	12.3	2.3	15.4	2.9
Segmented	54.6	31.5	54.5	29.0	54.6	35.1
Eosinophil	0.9	1.1	0.9	1.3	1.1	0.7
Basophil	0.3	0.2	0.4	0.2	0.2	0.1
Lymphocyte	24.9	58.6	26.4	60.6	22.7	55.6
Monocyte	5.0	6.1	4.7	6.5	5.2	5.5
N. per 100 WBC	1.2	0.1	1.2	0.1	1.2	0.0
Reticulocyte, %	2.3	0.4	2.4	0.4	2.2	0.3
Sternal marrow chamber count:						
Nucleated RBC and WBC	185,843	134,200	190,375	103,526	180,714	171,583
Megakaryocytes	58.7	82.9	74.3	62.3	40.9	105.3
Sternal marrow smear:						
Myeloblast	0.8	1.5	0.7	1.5	1.1	1.5
Myelocyte	16.3	19.7	17.0	18.1	15.9	22.1
Myelocyte Eo.	0.6	0.6	0.6	0.6	0.6	0.5
Nonsegmented	33.9	43.5	36.7	45.1	29.6	41.0
Segmented	7.0	10.4	6.8	10.4	7.2	10.5
Eosinophil	2.0	1.7	1.9	1.7	1.6	1.6
Basophil	0.0	0.0	0.0	0.0	0.0	0.0
Lymphocyte	3.8	6.2	3.4	6.7	4.2	5.5
Megakaryocyte	0.1	0.1	0.1	0.1	0.0	0.1
Hematogone	3.8	4.8	3.8	5.4	3.5	3.9
Reticulum	0.0	0.1	0.0	0.0	0.0	0.2
Megaloblast	0.1	0.1	0.1	0.1	0.1	0.0
Erythroblast	1.0	0.5	1.1	0.5	1.0	0.5
Normoblast	30.8	11.0	28.0	10.0	35.1	12.5
Total nucleated RBC	31.9	11.6	29.2	10.6	36.3	13.1
Myeloid-erythroid ratio	1.9	6.7	2.2	7.3	1.5	5.9

\* Thirty-five normal full term infants studied.

TABLE 46

COMPARISON OF ABSOLUTE COUNTS PER CUBIC MILLIMETER IN STERNAL MARROW DURING THE THREE TRIMESTERS OF PREGNANCY\*  
(Pitts and Packham, 1939)<sup>5</sup>

	Total Nucleated Cell Count per Cu. Mm.	(Granuloblasts: Myeloblasts)	Progranulocytes Type A (Promyelocytes Type A)	Progranulocytes Type S (Promyelocytes Type S)	Eosinophilic Granulocytes (Eosinophilic Myelocytes)	Neutrophilic Granulocytes (Neutrophilic Myelocytes)	Metagranulocytes (Meta- myelocytes)	Rhabdocytes (Unsegmented Polymorphonuclears)	Lobocytes (Segmented Polymorphonuclears)	Eosinophils	Basophils	Lymphocytes	Monocytes	Megaloblasts		Normoblasts		Disintegrated Cells
Trimester 1:																		
Maximum.	65,700	328	900	675	494	4336	5913	28,251	8835	1140	197	6309	965	136	1314	2628	2700	8100
Minimum.	14,400	0	38	0	28	172	259	2189	4050	48	0	2894	40	0	86	259	28	1382
Average.	34,580	63	378	262	218	2267	2165	11,659	5445	371	78	3975	333	56	749	1139	944	4684
Trimester 2:																		
Maximum.	125,000	1250	2500	3500	1440	13,125	10,250	46,250	11,750	990	125	10,000	642	203	1875	7000	2000	11,500
Minimum.	15,700	0	69	0	0	659	251	3077	1575	18	0	1686	0	0	251	314	250	1037
Average.	41,518	173	462	446	251	3229	2623	15,415	5441	299	47	4467	245	73	797	1803	835	4675
Trimester 3:																		
Maximum.	70,000	635	1460	1050	700	7937	4900	29,400	8680	700	191	5400	732	210	3937	8636	2730	11,900
Minimum.	16,900	0	0	51	0	391	340	4901	394	0	0	1318	0	0	51	51	119	1329
Average.	33,937	96	341	362	167	2138	1879	11,819	4613	228	49	3719	194	61	1050	1865	836	4480

\* Forty pregnant and 24 healthy nonpregnant women studied.

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## Chapter 11

### HEMATOLOGIC ERRORS

ERKSON, Magath and Hurn\* have evaluated the error in counting erythrocytes and leukocytes, assuming perfect technic with the usual hemocytometer method.

Three sources of inherent error not due to faulty technic are involved: using the pipette, filling the chamber, and counting cells in the chamber.

Their formulas for percentile coefficient of variation may be written:

$$\text{For red blood cells} \quad V = \sqrt{\frac{8464}{N_b} + \frac{21}{N_c} + \frac{22}{N_p}}$$

$$\text{For white blood cells} \quad V = \sqrt{\frac{10000}{N_b} + \frac{21}{N_c} + \frac{22}{N_p}}$$

Where  $V$  = coefficient of variation expressed as per cent of final count,  $N_b$  = total number of blood cells counted,  $N_c$  = number of separate counting chambers used, and  $N_p$  = number of separate pipettes used.

In these formulas the form is theoretical; the constants are based on their experimental measurements. In the technic usually employed,  $N_c$  and  $N_p = 1$ .

$$\begin{aligned} N_b &= \text{erythrocyte count} \div 10,000 \text{ (80 small squares counted)} \\ &= \text{leukocyte count} \div 50 \text{ (4 large squares counted)} \end{aligned}$$

With this technic properly conducted, the error is as follows:

The expected difference between consecutive counts on the same blood, without change in the blood, approximates one and one-half times the error shown on page 90.

The error shown for hemoglobin arises from filling the pipette. This is usually the major source of error except for faulty standardization of the measurement. Error of standardization is not in general susceptible to precision. The error for the differential count is given per hundred total white cells. It is based on the Poisson distribution error and assumes an evenly distributed smear of proper thickness (Table 47).

Because, half the time, differences in consecutive counts from the same unchanged blood differ by only one and one-half times the first column of values tabulated, a deceptive sense of reliability tends to be attached to single hematologic readings. Single unexpected measurements should arouse suspicion and should be repeated; of themselves they justify no reliable interpretation. Measurements of special importance should always be requested in duplicate, perhaps better, two in close sequence.

\* Am. J. Physiol., 128:309, 1940.

BLOOD CELLULAR ELEMENTS

TABLE 47

HEMATOLOGIC ERRORS

<i>Erythrocyte Count</i>		<i>Inherent Error Will Exceed</i>	
<i>(Millions)</i>		<i>10 Times out of 20</i>	<i>Once out of 20 Times</i>
5	.....	260,000	770,000
4	.....	220,000	640,000
3	.....	170,000	500,000
2	.....	120,000	370,000
1	.....	76,000	230,000
<i>Leukocyte Count</i>			
<i>(Number)</i>			
40,000	.....	2000	5900
20,000	.....	1100	3300
10,000	.....	650	1900
5,000	.....	400	1200
3,000	.....	290	870
1,000	.....	160	470
<i>Hemoglobin</i>			
<i>(Gm.:100 ml.)</i>		<i>Gm.</i>	<i>Gm.</i>
16	.....	0.5	1.5
12	.....	0.4	1.1
8	.....	0.3	0.8
<i>Differential Count</i>			
<i>(100 Cells)</i>			
<i>At Level Per Cent</i>		<i>Plus-Minus Per Cent Total Count</i>	<i>Plus-Minus Per Cent Total Count</i>
80	.....	6	18
40	.....	4	13
20	.....	3	9
10	.....	2	6
5	.....	2	4
2	.....	1	3
1	.....	1	2

### Section III

## CHEMICAL COMPONENTS AND PHYSICAL PROPERTIES OF BLOOD

Normal Values in Blood, Extracellular Fluids and Lymph)



## Chapter 12

### PHYSICAL PROPERTIES OF BLOOD

DATA PERTAINING to physical and chemical properties of the blood and body fluids become of daily importance in scientific medicine since it is practically impossible to examine a medical periodical without meeting statements about values in pathological conditions. Wherever possible, values obtained on normal subjects, not patients, have been collected. Values for such physical properties as coagulation time, bleeding time, resistance against hypotonic salt solutions and so forth are given in Chapter 8.

#### SPECIFIC GRAVITY

Table 48 gives specific gravity measurements of plasma, serum and corpuscles. The specific gravity of whole blood will obviously depend mainly on the percentage of cells present. For whole blood with a 45 per cent volume of cells, the specific gravity is approximately 1.055 at 20° C.

TABLE 48  
SPECIFIC GRAVITY OF BLOOD AT 20°C.

<i>Number of Subjects</i>	<i>Range</i>	<i>Average</i>	<i>Investigator</i>
.....	(Plasma) 1.0253-1.0287	1.0270	Moore and Van Slyke (1930)
.....	(Serum) 1.0245-1.0274	1.0260	Sunderman (1945)
.....	1.0241-1.0380	1.0293	Gettler and Baker (1916)
.....	(Corpuscles)		
not given.....	1.0880-1.0889	1.0885	Schmidt (quoted by Gram 1924)

SPECIFIC GRAVITY AND SERUM WATER. Sunderman<sup>9</sup> presented the correlation of specific gravity and water in serum. The specific gravity measurements were made at 20° C. with pycnometers of 2 ml. capacity. The amount of total solids was determined by drying a weighed amount of serum at 100° to 105° C. to constant weight. The water per kilogram of serum was calculated from the measurement of the total solids.\*

\* In the calculations the following relationships are used:

$$X/K = (X/L)/Sp; H_2O/K = 1000 - S/K; [X] = \frac{X/L \cdot 1000}{H_2O/K \cdot Sp}$$

where  $Sp$  represents specific gravity at 20° C.,  $H_2O$  water in gm.,  $S$  solids in gm.,  $X$  a solute in gm.,  $L$  liters of serum,  $K$  kilos of serum,  $[X]$  concentration per kilogram of water.

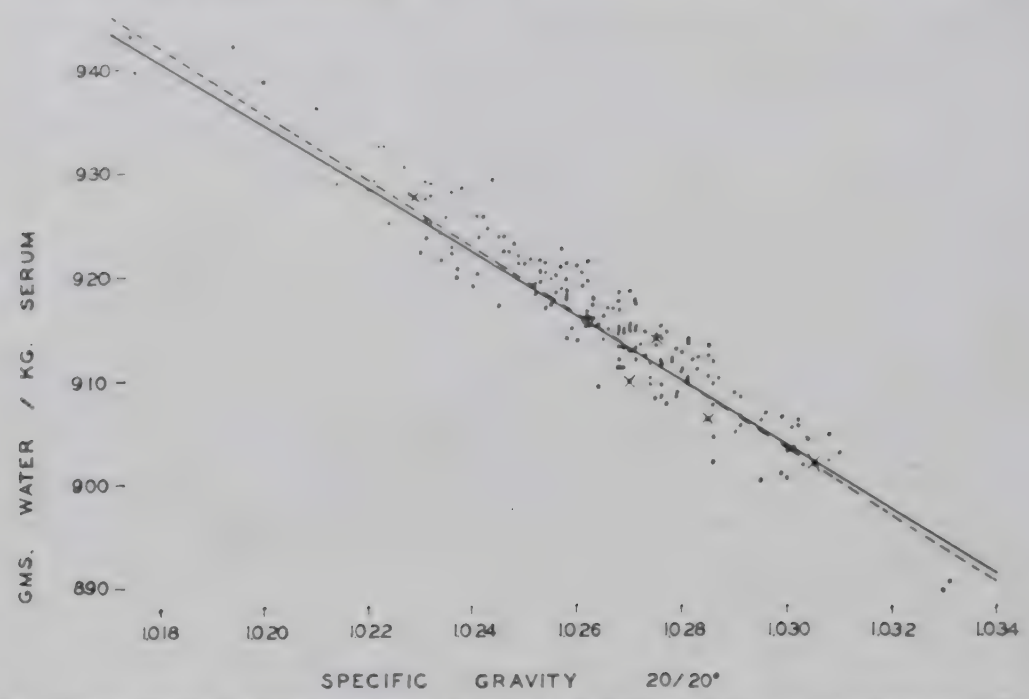


Fig. 37. The water of serum plotted against the specific gravity. (Sunderman, F. W.: J. Biol. Chem., vol. 113.)

TABLE 49

SERUM WATER AND FACTORS FOR CALCULATION OF MOLALITY OF A SOLUTE (X) IN SERUM WHEN SPECIFIC GRAVITY HAS BEEN MEASURED

(Sunderman, 1936)<sup>9</sup>

<i>Sp. Gr. 20°/20°</i>	<i>Water per Kilogram Serum (Gm.)</i>	<i>Water per Liter Serum (Gm.)</i>	<i>Multiplying Factors for Conversion of X per Liter Serum to X per Kilogram H<sub>2</sub>O in Serum</i>
1.015.....	952	966	1.035
1.016.....	948	964	1.038
1.017.....	945	916	1.040
1.018.....	942	959	1.043
1.019.....	939	957	1.045
1.020.....	936	954	1.048
1.021.....	932	952	1.051
1.022.....	929	949	1.053
1.023.....	936	947	1.056
1.024.....	923	945	1.059
1.025.....	919	942	1.061
1.026.....	916	940	1.064
1.027.....	913	938	1.067
1.028.....	910	935	1.069
1.029.....	906	933	1.072
1.030.....	903	930	1.075
1.031.....	900	928	1.078
1.032.....	897	925	1.081
1.033.....	894	923	1.083
1.034.....	890	921	1.086

The statistically calculated regression line of water on specific gravity is shown as a solid line in Figure 37, and may be expressed by Equation 1:

$H_2O/K = 4082.3 = 3086.3 \text{ Sp.}$

Theoretically, the limiting value of the line should extrapolate to a specific gravity of 1.000 when H<sub>2</sub>O is 1000. The dotted line shown on Figure 37 is corrected to pass through this limiting value and may be expressed by Equation 2:

$H_2O/K = 4225.6 - 3225.6 \text{ Sp.}$

Since the corrected regression line is well within twice the scattering of the data and since the water values obtained by Equation 2 over the range of the specific gravity values observed in serum are within plus or minus 0.2 per cent of those obtained by Equation 1, Equation 2 is preferable to Equation 1.

SPECIFIC GRAVITY FACTORS. Table 49 gives the factors by which for any serum specific gravity the concentration of a solute per liter of serum may be calculated as the concentration per kilogram of water. In addition, the gram water and solids per kilogram or liter of serum may be obtained directly from the table for any serum specific gravity.

SPECIFIC CONDUCTIVITY OF SERUM

Conductivity measurements of serum may be used to calculate the concentration of total base in serum, provided a correction is made for either the serum proteins or specific gravity (Fig. 38).

TABLE 50  
SERUM CONDUCTIVITY AT 20°C. AND 25°C.

<i>Number of Subjects</i>	<i>Range of Specific Conductance Mhos 10<sup>3</sup></i>	<i>Average</i>	<i>Investigator</i>
	11.73-12.29	11.90 at 25°C.	Sunderman (1945)
	10.48-11.10	10.63 at 20°C.	Gram (1924)
	11.65-12.39	11.99 at 25°C.	Atchley et al. (1923)

TABLE 51  
TOTAL BASE, CONDUCTIVITY AND SPECIFIC GRAVITY MEASUREMENTS ON SERUMS OF 8 NORMAL SUBJECTS  
(Sunderman, 1945)<sup>9</sup>

<i>Subjects</i>	<i>Observed Total Base MEq./l</i>	<i>Observed Specific Conductance, 25°C. Mhos Multiplied by 10<sup>3</sup></i>	<i>Specific Gravity 20°/20°</i>
1	142.8	11.73	1.0265
2	143.0	11.78	1.0253
3	144.0	11.82	1.0264
4	146.0	11.86	1.0274
5	146.2	12.03	1.0257
6	146.4	11.82	1.0252
7	146.5	12.29	1.0257
8	147.2	11.86	1.0272

Figure 38 may be used for calculating serum total base from measurements of specific conductivity and serum protein.

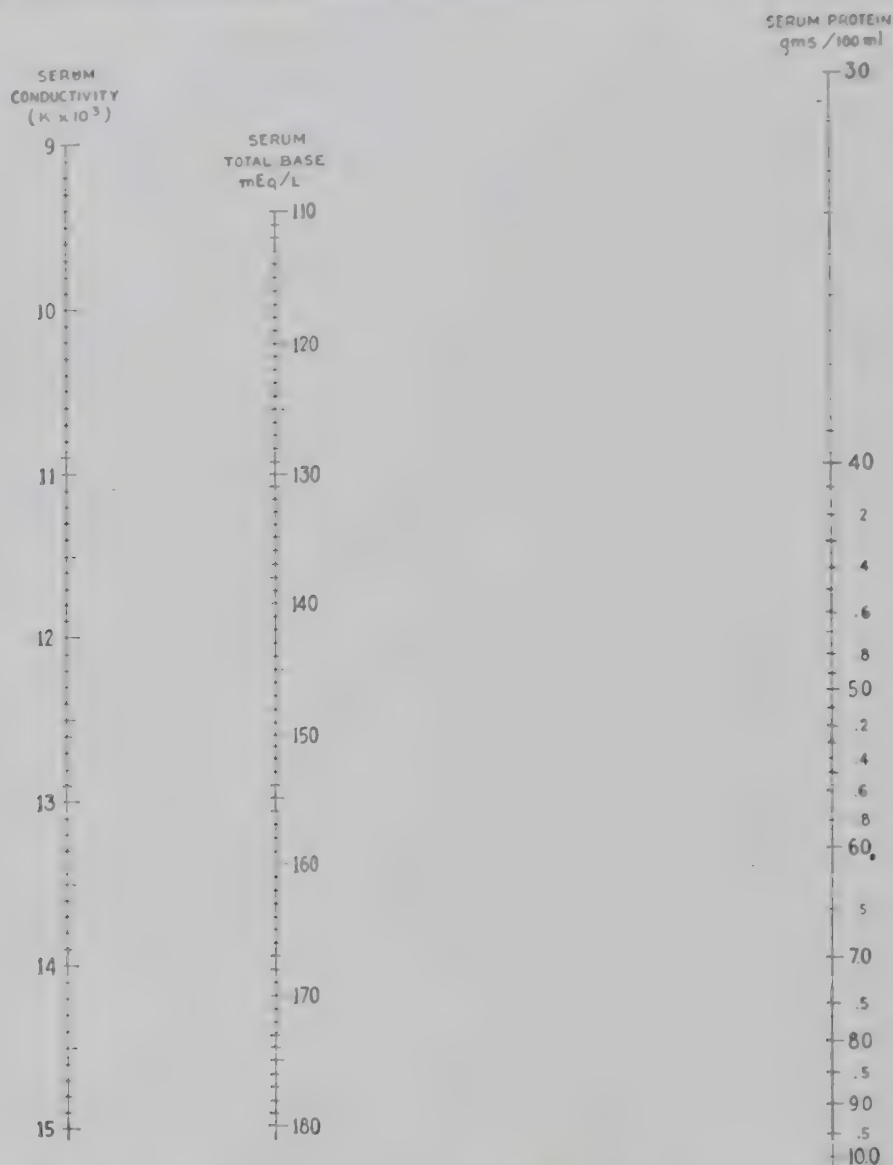


Fig. 38. Nomogram for calculating serum total base. The serum conductivity and serum protein values should be connected by a straight line. The intersection of this line with the inner scale gives the value for the serum total base.

The values of the variates in the nomogram are obtained from the statistically derived regression formula:

$$T.B. = 10.19 (K \times 10^3) - \frac{69.45}{Pr.} + 35.16$$

where  $T.B.$  = total base in milliequivalents per liter;  $K \times 10^3$  = specific conductance  $\times 10^3$  at 25°C.; and  $Pr.$  = grams of protein per 100 ml. (Lufkin, H. M., and Sunderman, F. W.: Am. J. Clin. Path., vol. 16.)

## REFRACTIVE INDEX

Measurement of the refractive index of serum affords a rapid method of estimating the concentration of serum proteins.<sup>2</sup> The refractivity measurements are made by placing one drop of serum in the chamber of an Abbe refractometer and reading the refractive index. From this value is subtracted

the refractive index of water at the same temperature. The values of the refractive index of water may either be measured directly or may be obtained for any given temperature from prepared refractivity tables.<sup>3</sup> For this measure-

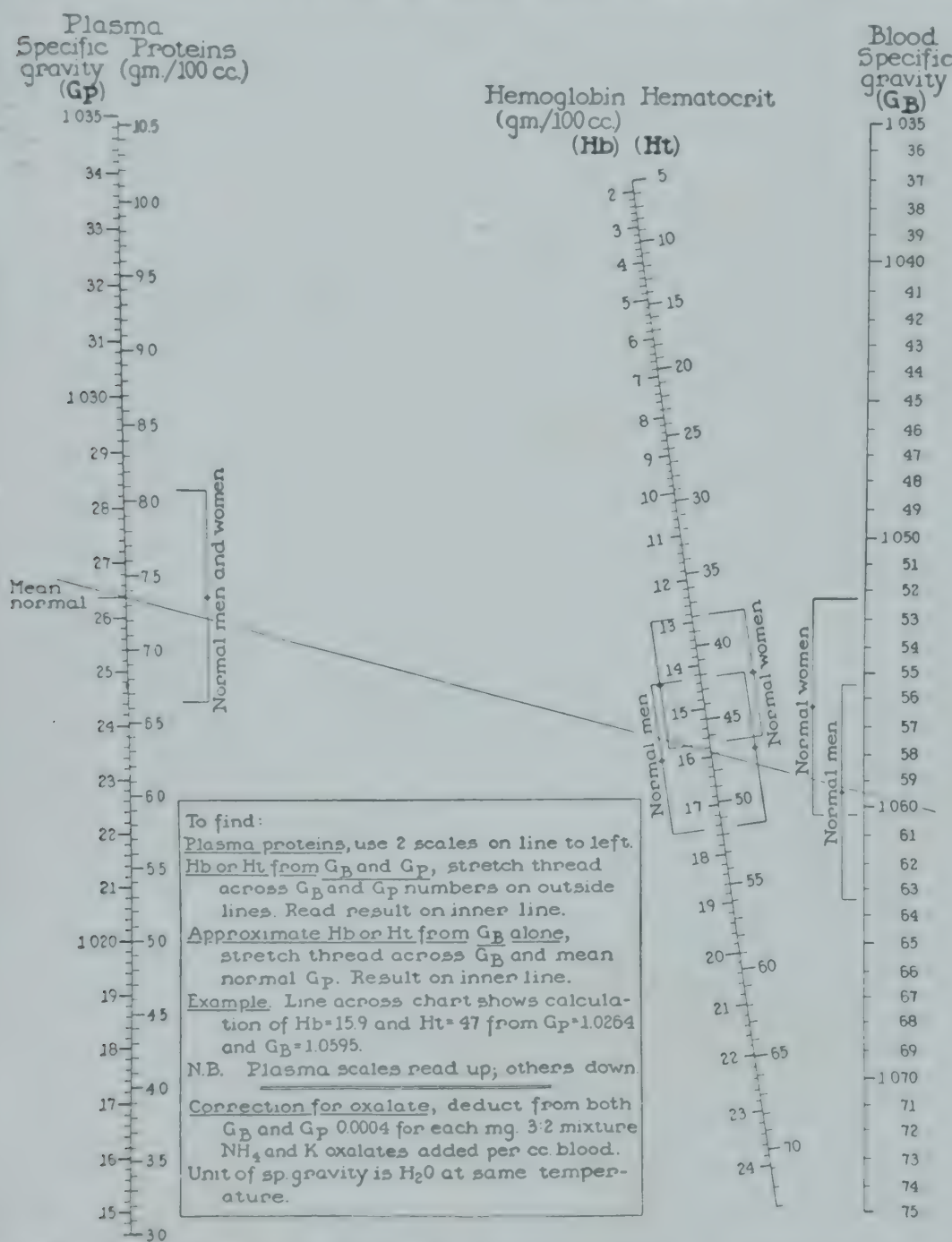


Fig. 39. Nomogram for the calculation of plasma protein, hemoglobin and hematocrit from plasma and whole blood specific gravities. (Phillips, R. A., et al.: Bull. U.S. Army Med. Dept., No. 71.)

ent it is sufficiently accurate to calculate the refractive index of water at any temperature by the following formula:

$$R.I. \frac{(t)}{H_2O} = 1.332 - [0.0001(t) - 0.0018]$$

If distilled water is not available for direct measurement, tap water may be used without introduction of any appreciable error.

TABLE 52  
REFRACTIVE INDEX OF SERUM AT 17.5°C. ABBE REFRACTOMETER, REFRACTIVE INDEX OF DISTILLED WATER BEING 1.3332)

Number of Normal Subjects	Refractive Index		Investigator
	Maximum	Minimum	
12.....	1.3511	1.3492	Gram (1924)
10.....	1.3505	1.3485	Sunderman (unpublished)

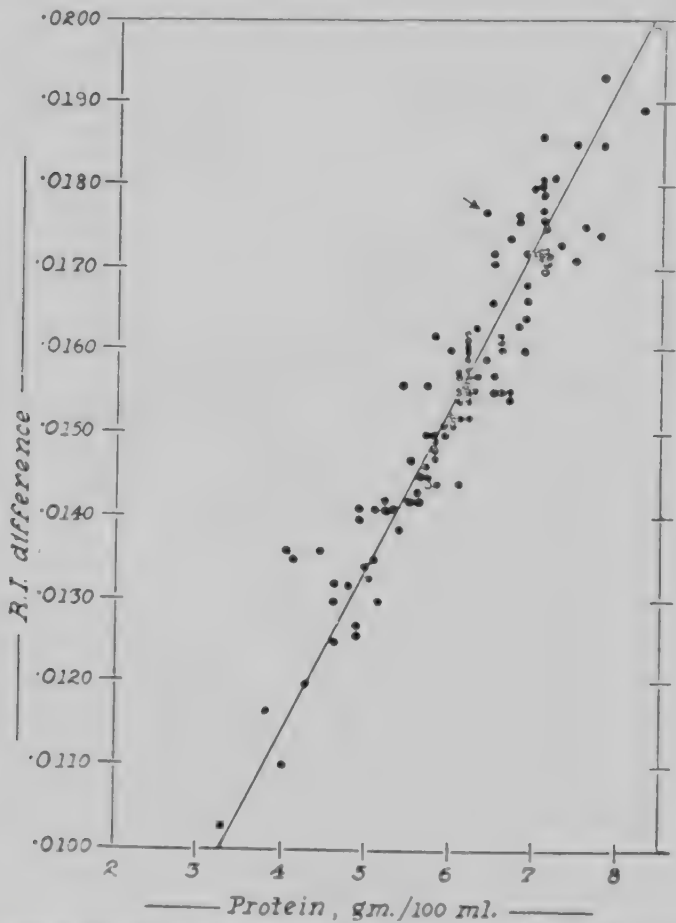


Fig. 40. Refractometer values plotted against serum protein. The equation for the statistically calculated regression line is

$$\text{Pr} = 510 \text{ R.I.}_{\text{diff.}} - 1.81$$

The point indicated by the arrow represents a specimen with a high concentration of bilirubin. (Sunderman, F. W.: J. Biol. Chem., vol. 153.)

When the differences in the refractive index of serum and water are plotted against the serum protein concentrations, an excellent linear correlation is obtained (Fig. 40). The statistically calculated regression line derived from this correlation may be expressed by the equation:

$$\text{Pr.} = 510 \text{ R.I.}_{\text{diff.}} - 1.81$$

$r_s$  = grams of protein per 100 ml.;  $R.I._{diff}$  = the refractive index of serum minus the refractive index of water). The standard deviation for this regression line is equal to 0.31 gm. of protein per 100 ml. of serum.

VISCOSITY

The fluidity ( $\phi_r$ ) of any sample of plasma or other fluid relative to water at the same temperature may be calculated as follows:

$$\phi_r = \frac{P_w T_w}{P_x T_x}$$

where  $T_w$  and  $T_x$  represent the time of efflux of water and the unknown, and  $P_w$  and  $P_x$ , the pressure heads of water and the unknown.

According to Gram,<sup>3</sup> the temperature correction for viscosity measurements with the Hess viscosimeter is plus 0.8 per cent for each degree increase in temperature between 15° and 25° C.

TABLE 53  
VISCOSITY OF PLASMA, SERUM AND BLOOD

<i>Number of Subjects</i>	<i>Type</i>	<i>Range of Relative Fluidity</i>	<i>Average</i>	<i>Method</i>	<i>Investigator</i>
.....	Plasma	0.500 to 0.603	0.555	Mann viscometer	Mann (1948)
not given.....	Serum	1.7 to 2.0	.....	Hess viscosimeter	Gram (1924)
not given.....	Blood	3.6 to 5.4	.....	Hess viscosimeter	Gram (1924)

FREEZING POINT DEPRESSION

One mole of a solute in a kilogram of water lowers the freezing point 1.858° C. Since the freezing point depression of serum averages 0.55° C., the milliosmolar concentration of serum is approximately 300 milliosmols. The normal concentration of electrolytes (total base) is approximately 145 milli-

TABLE 54  
FREEZING POINT DEPRESSION ( $\Delta$ ) OF SERUM

<i>Number of Subjects</i>	$\Delta - ^\circ\text{C.}$		<i>Investigator</i>
	<i>Range</i>	<i>Average</i>	
not given.....	0.555-0.570	0.562	Gram (1924)
6.....	0.550-0.570	0.557	Sunderman, Austin and Camac (1926)
5.....	0.531-0.543	0.535	Sunderman, Austin and Williams (1932)
10.....	0.535-0.555	0.547	Sunderman (1945)

equivalents per liter. If, at this concentration, the total base is assumed to be 95 per cent dissociated, the milliosmolar concentration, owing to electrolytes, is approximately 283 milliosmols. The remaining milliosmols contributing to the total osmotic pressure are those of nonelectrolytes such as urea and glucose.

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## Chapter 13

# PROTEIN AND NONPROTEIN COMPONENTS OF BLOOD PLASMA

## BLOOD PROTEINS AND NONPROTEIN NITROGEN

### SERUM PROTEIN

THE NORMAL range of concentrations for serum protein is usually considered to be 6.5 to 6.9 gm. per 100 ml.; for plasma protein, 6.5 to 7.5 gm. per 100 ml. Luetscher,<sup>11</sup> using electrophoretic patterns, gives the mean value for normal plasma proteins as 6.5 gm. per 100 ml. Dole and Braun<sup>7</sup> give the mean value for plasma protein as 6.72, and for serum protein as 6.38 gm. per 100 ml.

The standard method for the determination of serum protein is by digestion and oxidation (Kjeldahl principle), converting nitrogen to the form of ammonia, which is distilled into acid and determined by stoichiometric titration or nesslerization. The protein is calculated as follows:

$$\text{Grams of nitrogen} \times 6.25 = \text{grams of protein}$$

### FRACTIONATION OF SERUM PROTEINS

In recent years much emphasis has been placed upon changes in the serum protein fractions occurring in edema and to some extent in dehydration. Methods should be made of the electrophoretic method as an important laboratory development for such fractionations. With this method the different serum proteins are caused to migrate in electrical fields and the refractometric analysis of the stratification is determined photographically. The amount of the protein fractions may be calculated from the areas produced by the photographed patterns. In Figure 40a is shown the normal plasma electrophoretic pattern. The tall peaks represent the albumin fraction. The  $\alpha_1$ ,  $\alpha_2$ ,  $\beta$ ,  $\phi$ , and  $\gamma$  peaks denote the globulin components—the  $\phi$  peak denoting fibrinogen. The spike,  $\delta$  and  $\epsilon$  peaks represent principally buffer salt gradients with which we are concerned.

It has been shown that no clear-cut division of the serum proteins is obtained from their solubilities in ammonium or sodium sulfate. On the other hand, by electrophoresis, it would appear that the proteins may be separated in pure form and the various fractions identified with greater accuracy.

In clinical medicine the fractionation of the serum protein has usually been carried out by salting-out procedures in which the globulins are precipitated either by half-saturation with ammonium sulfate<sup>5</sup> or by sodium sulfate.<sup>12</sup> The concentration of serum globulin is estimated by subtracting the serum albumin concentration from the total protein concentration. Pillemer and Hutchinson<sup>13</sup> have used methanol as the precipitating agent for the globulins and obtain

fractions which agree in purity and amount with those obtained electrophoretically.

By electrophoretic studies normal human serum is found to contain albumin and three globulin fractions:  $\alpha$ ,  $\beta$  and  $\gamma$ . These fractions do not correlate

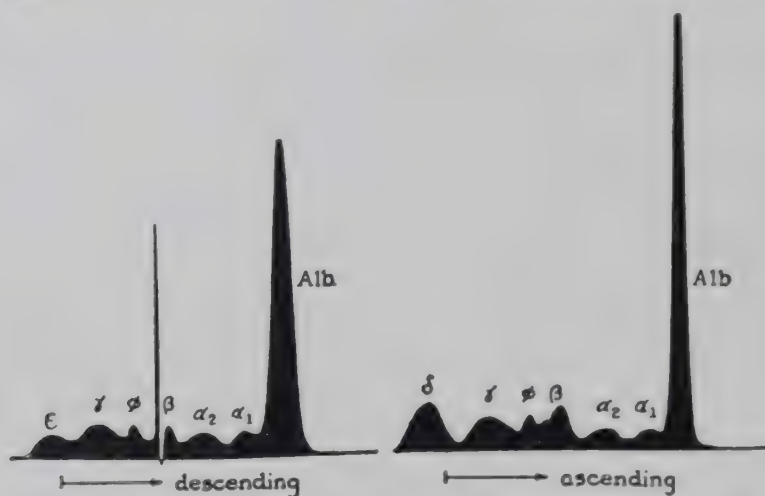


Fig. 40a. The electrophoretic pattern of normal plasma. (After Dole: J. Clin. Investigation, vol. 23.)

well with the fractions obtained by salting-out procedures. The approximate relative percentages are albumin, 58;  $\alpha$  globulin, 14;  $\beta$  globulin, 13;  $\gamma$  globulin, 11; fibrinogen, 4.

#### RELATIVE DIMENSIONS OF VARIOUS PROTEINS

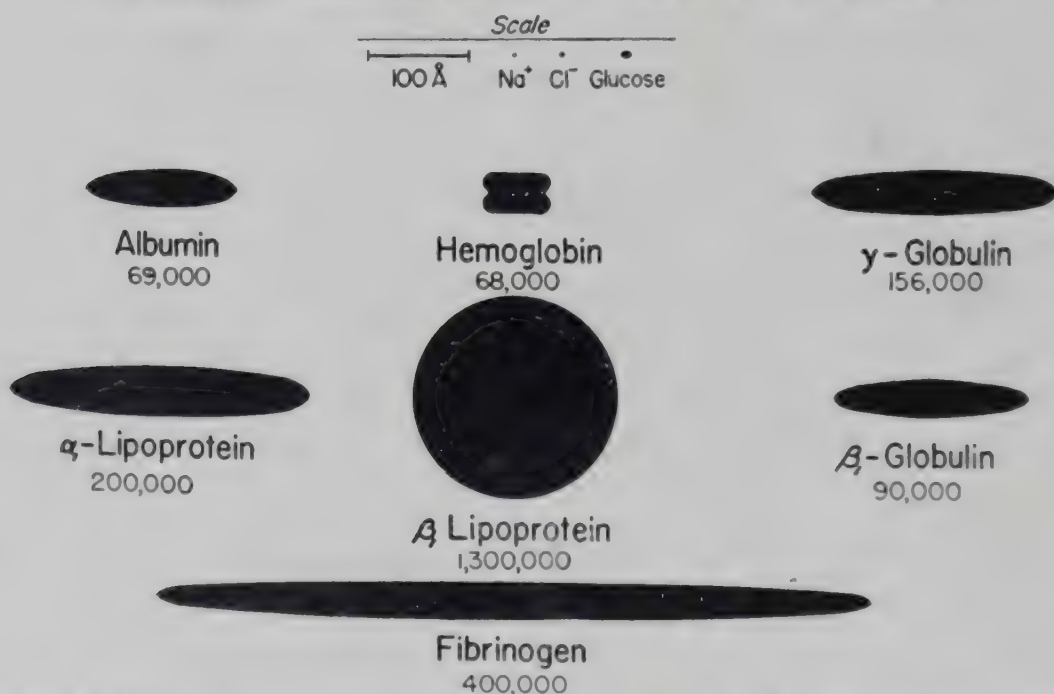


Fig. 41. Relative dimensions of various proteins in blood. [Revised by J. L. Oncley, from Am. Scientist, vol. 33.]

In normal human serum the electrophoretic pattern is essentially unchanged after removal of euglobulin (precipitation with 13.5 per cent sodium sulfate).

Precipitation in 17.4 per cent sodium sulfate (euglobulin and pseudoglobulin I) removes about one-half the  $\alpha$  globulin and one-fourth of the  $\beta$  globulin (none of the  $\gamma$  globulin). Precipitation in 21.5 per cent sodium sulfate removes all  $\gamma$  globulin, about three-fourths of  $\beta$  globulin and one-fourth of the  $\alpha$  globulin.

There is a considerable amount of  $\alpha$  and  $\beta$  globulins in the albumin fraction estimated by salting-out procedures.

When precautions to avoid loss of albumin by adsorption are not observed, values for albumin will be slightly lower, and, as globulin is determined by difference, its value will be correspondingly higher.<sup>16</sup> *Normal values for albumin may be as low as 4.0 gm. per 100 ml., and globulin values as high as 3.0 gm. per 100 ml.* At birth the concentration of serum protein in the normal infant is approximately 5 gm. per 100 ml., and the protein contains little globulin. This value rises steadily during the first year of life, and by the fifteenth to eighteenth month reaches the values found in adults.

TABLE 55  
PARTITION OF SERUM PROTEINS\*

	Mean Values (Gm./100 Ml.)	Standard Deviation
Total protein.....	7.2	±0.35
Albumin.....	5.2	±0.25
Total globulins.....	2.0	±0.27
Euglobulin.....	0.2	±0.11
Pseudoglobulin I.....	1.3	±0.23
Pseudoglobulin II.....	0.5	±0.16

\* Globulin precipitation with sodium sulfate. Values are those of Gutman, Moore, Gutman, McClellan and Kabat,<sup>9a</sup> obtained on blood serum of 36 normal adults.

TABLE 56

SERUM AND PLASMA PROTEINS OF INFANTS  
(Smith, 1945)<sup>18</sup>

Material	Age of Subjects	Number of Subjects	Gm./100 Ml.			Method	Investigator
			Maximum	Minimum	Average		
Plasma	Birth	40	6.31	5.46	5.89	Micro-Kjeldahl	Pommerenke (1936)
Serum	1 day	9	6.98	4.60	5.78	Refractometry	Ruiz (1912)
	2-3 days	13	6.47	4.70	5.78		
	11-15 days	6	6.34	5.31	5.78		
	2-12 wks.	19	7.48	4.96	6.12		
Serum	1 day	14	.....	.....	6.25	Refractometry	Utheim (1920)
	2 days	12	.....	.....	5.80		
	3 days	12	.....	.....	6.33		
	5 days	13	.....	.....	5.59		
	10 days	3	.....	.....	6.19		
	1 month	3	.....	.....	6.29		
Serum	Birth to 7th day	125	.....	.....	6.5	Refractometry	Bakwin (1922)
Serum	5-22 days	26	(Slightly higher 1st, 7.83	higher 1st, 6.26	2d, 3rd days) 7.04	Colorimetric	Ray and Phatak (1930)
	1-9 days	40	7.71	5.14	6.24	Refractometry	Marples and Lippard (1932)
Serum	Cord blood	25	7.7	5.3	6.4	Micro-Kjeldahl	Andersch and Oberst (1936)

Serum	Card blood 1-2 days 3-4 days 5-6 days 7-8 days	79 17 20 21 15	7.43 7.02 6.67 7.01 6.60	5.15 5.10 5.15 5.10 5.10	6.04 6.03 5.89 6.02 5.93	Refractometry	Denzer, Reiner, Weiner (1939)
Serum	"Newborn" 5-6 months	20 14	7.0 7.0	4.5 5.8	5.52 6.29	Kjeldahl	Darrow, Cary (1933)
Serum	First 2 days 2-11 months	17 16	.....	.....	5.11 6.10	Micro-Kjeldahl and salt preparation	Rapoport et al. (1943)

*Premature Infants*

Serum	6-90 days	26	7.0	3.8	4.94	Kjeldahl	Darrow, Cary (1933)
Serum	1-68 days	17	.....	.....	4.55	.....	Rapoport et al.
Plasma	3-5 days 8-18 days	12 8	5.36 5.02	3.62 3.80	4.62 4.42	Micro-Kjeldahl	Young et al. (1941)

TABLE 57

DISTRIBUTION OF SERUM PROTEIN, SERUM ALBUMIN AND GLOBULIN, AND THE ALBUMIN-GLOBULIN RATIO IN NORMAL INFANTS\*

(Darrow and Cary, 1933)<sup>6</sup>

20 Normal Newborn Infants

	<i>Range</i>	<i>Average</i>	<i>Standard Deviation</i>
Total protein (gm./100 ml.) . . . . .	4.6-6.9	5.52	±0.58
Albumin . . . . .	3.1-4.4	3.73	±0.31
Globulin . . . . .	1.6-2.6	1.78	±0.45
A/G ratio . . . . .	1.5-3.5	2.16	±0.37

14 Normal Infants

Total protein . . . . .	5.9-6.9	6.29	±0.33
Albumin . . . . .	3.6-4.9	4.28	±0.38
Globulin . . . . .	1.6-2.9	2.01	±0.34
A/G ratio . . . . .	1.3-2.6	2.14	±0.44

\* Fractionations made by precipitating the globulin with sodium sulfate.

TABLE 58

CONCENTRATIONS OF SODIUM SULFATE AND SODIUM SULFITE REQUIRED TO PRECIPITATE THE PROTEINS OF BLOOD SERUM

	<i>Sodium Sulfate</i> <sup>10</sup>		<i>Sodium Sulfite</i> <sup>2</sup>	
	Moles/liter	Gm./100 Ml.	Moles/liter	Gm./100 ml.
Fibrinogen . . . . .	0.76	10.6	0.906	11.4
Euglobulin . . . . .	1.00	14.2	1.131	14.25
Pseudoglobulin I-E . . . . .	1.25	17.7	1.355	17.1
Total globulin . . . . .	1.50	21.5	1.58	19.95

TABLE 59

SERUM ALBUMIN AND ALBUMIN GLOBULIN RATIOS BY DIFFERENT METHODS

Serum	Albumin, Gm./100 Ml.			Albumin/Globulin, Ratio		
	Method			Method		
	Electro-phoretic	Precipita-tion with Methanol	Precipita-tion with Sodium Sulfate	Electro-phoretic	Precipita-tion with Methanol	Precipita-tion with Sodium Sulfate
lemer and Hut- chinson, 1945						
1	3.98	4.12	4.58	1.5	1.6	2.2
2	4.40	4.41	5.20	1.5	1.5	2.5
3	4.10	4.24	4.22	1.54	1.6	1.6
4	3.95	4.00	....	1.25	1.3	..
wson and Sunder- man, 1947)						
1.....	....	4.00	4.97	....	1.4	2.7
2.....	....	4.09	4.79	....	1.7	2.7
3.....	....	4.26	5.00	....	1.7	2.7
4.....	....	4.23	4.87	....	1.3	2.0
5.....	....	3.40	4.38	....	1.0	1.9

TABLE 60

PROTEIN COMPONENTS OF NORMAL HUMAN PLASMA CHARACTERIZED BY PHYSICAL  
CHEMICAL METHODS

(Cohn, 1947)<sup>3</sup>

Electrophoretic Component	Fraction (Cohn)*	Approximate Amount in Plasma (Gm/1)	Sedimen- tation Constant <i>s</i> <sub>20,w</sub>	Intrinsic Viscosity <i>H</i> <sub>0</sub> × 10 <sup>3</sup>	Molecular Weight ( <i>M</i> )	Approximate Dimensions in Å	
						Length	Diameter
albumin.	V	32	4.6	4.2	69,000	150	38
Globulin....	IV-1	2	5.0	6.6	200,000	300	50
	IV-4	1	4-5	...	(70,000)	...	...
Globulin....	IV-6	1	9.0	9.2	(300,000)	...	...
Globulin....	IV-7	2	5.5	5.5	90,000	190	37
	III-0,III-2	2	7.0	...	(150,000)	...	...
	III-0	1	20.0	...	500,000- 1,000,000		
	III-0	2	X	4.1	1,300,000	185	185
Globulin....	III-1	2	7.0	...	(150,000)	...	...
Globulin....	II	5	7.2	6.0	156,000	235	44
	II	1	10.0	...	(300,000)	...	
inogen....	1-2	2	9.0	25.0	400,000	700	38

\* For information regarding preparation and estimations of "Fractions," reference should  
be made to the original.

TABLE 61

AMINO ACID COMPOSITION OF PROTEIN FRACTIONS FROM NORMAL HUMAN SERUM  
(From Brand, 1946)<sup>1</sup>

Constituent	Albumin* Assumed Mol. Wt. — 70,000		$\gamma$ Globulin* Assumed Mol. Wt. — 156,000	
	Gram of Amino Acid per 100 Gm. of Protein	Gram of Amino Acid Residue per 100 Gm. of Protein	Gram of Amino Acid per 100 Gm. of Protein	Gram of Amino Acid Residue per 100 Gm. of Protein
Glycine.....	1.6	1.2	4.2	3.2
Valine.....	7.7	6.5	9.7	8.2
Leucine.....	11.9	10.3	9.3	8.0
Isoleucine.....	1.7	1.5	2.7	2.3
Proline.....	5.1	4.3	8.1	6.8
Phenylalanine.....	7.8	7.0	4.6	4.1
Cysteine.....	0.70	0.60	0.70	0.60
Half-cystine.....	5.58	4.74	2.37	2.01
Methionine.....	1.28	1.13	1.06	0.93
Tryptophan.....	0.19	0.17	2.86	2.61
Arginine.....	6.15	5.51	4.80	4.30
Histidine.....	3.5	3.1	2.50	2.21
Lysine.....	12.3	10.8	8.1	7.1
Aspartic acid.....	10.4	9.0	8.8	7.6
Glutamic acid.....	17.4	.....	11.8	.....
Amide —NH <sub>3</sub> .....	1.07	.....	1.35	.....
Glutamine†.....	.....	8.05	.....	10.15
Free glutamic acid.....	.....	7.16	.....	0.12
Serine.....	3.7	3.1	11.4	9.5
Threonine.....	5.0	4.2	8.4	7.1
Tyrosine.....	4.66	4.20	6.75	6.08
"Terminal H <sub>2</sub> O".....	.....	0.24	.....	0.14
Total.....	107.7	92.8	109.5	93.1
Water taken up on hydrolysis = 14.9		Water taken up on hydrolysis = 16.4		

\* Prepared by the Department of Physical Chemistry, Harvard Medical School.

† All the amine NH<sub>3</sub> has been arbitrarily assigned to glutamine.

TABLE 62

NITROGEN PARTITION OF ALBUMIN AND GAMMA GLOBULIN FROM NORMAL HUMAN SERUM  
(After Brand, 1946)<sup>1\*</sup>

Nitrogen	Grams per 100 Gm. of Protein	
	Albumin	$\gamma$ Globulin
Total nitrogen	15.95	16.03
Amide	0.880	1.11
Indole	0.013	0.20
Guanidino	1.500	1.16
Imidazole	0.641	0.45
$\epsilon$ -Amino	1.181	0.78
Non- $\alpha$	4.215	3.70
$\alpha$	11.735	12.33
Total free amino	1.38	0.89
Free $\alpha$ amino	0.18	0.11
Peptide	11.555	12.22

\* For molecular calculation, mean values of 156,000 for  $\gamma$  globulin and 70,000 for albumin be taken.

FIBRINOGEN (FIBRIN)

The normal range of values is 0.2 to 0.4 gm. per 100 ml. The various methods on this range. For example, Gram<sup>6</sup> gives the following variations in the concentration of fibrogen in the blood plasma of normal subjects:

	Range	Average
25 normal men	0.20 to 0.36	0.27
25 normal women	0.21 to 0.39	0.29

From these figures one would conclude that there is no significant difference in fibrogen to sex. Mylon and his co-workers<sup>13</sup> indicate that, by their method (determination with protamine), the values are 20 per cent higher than by other methods.

NONPROTEIN NITROGEN CONSTITUENTS

To some extent the value for nonprotein nitrogen will depend upon the precipitating agent. According to Seibert,<sup>17</sup> trichloroacetic acid precipitates albumin and globulin, whereas phosphotungstic acid precipitates albumin, globulin and proteoses.

AMMONIA IN THE BLOOD

The range of the normal concentration of ammonia in the blood is usually given as 0.1 to 0.3 mg. per 100 ml. Conway and Cooke,<sup>4</sup> however, have shown that if normal blood is drawn in an atmosphere of carbon dioxide, the ammonia nitrogen concentration is only 0.004 mg. per 100 ml.

UREA IN THE BLOOD

The normal concentration of urea in whole blood varies from 19 to 32.5 mg. per 100 ml.; in terms of urea nitrogen, from 8.9 to 15.2 mg. (Table 63). Men appear to have higher concentrations than women, as shown by the studies of MacKay and MacKay (Table 64).

TABLE 63

PARTITION OF NONPROTEIN NITROGEN IN THE BLOOD OF NORMAL INDIVIDUALS AND THE DISTRIBUTION OF THE VARIOUS NITROGENOUS CONSTITUENTS BETWEEN THE CELLS AND PLASMA

(Compiled by F. W. Sunderman)

	Plasma or Serum			Whole Blood			Corpuscles		
	Minimum (Mg./100 Ml.)	Maximum (Mg./100 Ml.)	Average (Mg./100 Ml.)	Minimum (Mg./100 Ml.)	Maximum (Mg./100 Ml.)	Average (Mg./100 Ml.)	Minimum (Mg./100 Ml.)	Maximum (Mg./100 Ml.)	Average (Mg./100 Ml.)
Total nonprotein nitrogen	22	29	25	28	39	32	38	55	44
Urea nitrogen	9.6	17.6	12	8.9	15.2	12.0	8	13	10
Urea	20.3	37.6	26	19.0	32.5	25.6	17	28	21
Nonurea nitrogen	6	18	12	16	26	20	25	45	33
Amino acid nitrogen	3.4	5.0	4.4	4.6	6.8	5.6	6.5	9.6	7.4
Uric acid nitrogen	0.7	1.3	1.3	0.3	1.3	0.7			
Uric acid	2.0	4.0	3.0	1.0	3.0	2.0			
Creatinine nitrogen	0.4	0.5	0.4	0.4	0.6	0.5			
Creatinine	1.0	1.3	1.1	1.2	1.5	1.3			
Creatine nitrogen				1.0	1.6	1.3	1.9	3.2	2.6
Creatine				3.0	5.0	4.0	6.0	10.0	8.0
Glutathione nitrogen				4.4	4.8	4.6	9.5	10.5	10.0
Glutathione				24.0	26.2	25.1	53.3	57.5	54.7
Nucleotide nitrogen				4.4	7.4	5.8	10	16	13
Ergothionine nitrogen						3.3 ± 1.5			6.4 ± 2.7
Ergothionine						18.0 ± .8			35.0 ± 15
Phenols (substituted)						1.5 ± 0.5			
Guanidine			8.0 ± 2			0.4 ± 0.1			
Glutamine			0.65 ± 0.35						
Citrulline			0.25 ± 0.2						
Indican			0.5 ± 0.3						
Bilirubin			0.2						
Crobin									
Ammonia (see text)				0.1	0.3				

TABLE 64

CONCENTRATION OF BLOOD UREA IN RELATION TO SEX (BLOOD UREA CONCENTRATION, MILLIGRAMS PER 100 ML. BLOOD)\*  
(MacKay and MacKay, 1927)<sup>12</sup>

	All Observations	Males	Females
Number of observations.....	278†	(58)	58
Mean.....	48.0	46.2	39.0
Standard deviation.....	11.0	25.8	11.0
Mean value.....	29.3	33.0	24.4
Standard deviation.....	6.98	4.60	5.88
Probable error of the average.....	0.28	0.40	0.52
Coefficient of variability.....	4.01	8.70	8.85

To convert to concentrations of blood urea *nitrogen*, multiply by the factor 0.467.  
Two hundred and twenty observations on 114 males and 58 observations on 47 females.

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## Chapter 14

### BLOOD SUGAR

THE REDUCING substance in blood is chiefly glucose. The material determined by the usual reduction methods includes, however, some nonglucose-reducing substance. The amount of nonglucose-reducing substances reported by Hiller, Linder and Van Slyke<sup>1</sup> is from 15 to 30 mg. per cent.

The normal values for blood sugar depend to some extent upon the method employed for its determination. *It is, however, safe to assume the range to be from 70 to 120 mg. per 100 ml. for adults whenever the procedure is not given or the laboratory performing the test does not advise to the contrary* (see Table 65 and Fig. 42).

TABLE 65

VALUES FOR NORMAL FASTING BLOOD SUGAR IN ADULTS

(Rudesill and Henderson, 1941)<sup>5</sup>

<i>Method</i>	<i>Blood Sugar Value (Mg. per 100 cc.)</i>	<i>Investigator</i>
Not stated . . . . .	90 to 120	Todd and Sanford (1939)
Several methods . . . . .	70 to 120	
Folin-Wu . . . . .	90 to 120	
Folin-Malmros micromethod . . . . .	75 to 105	
Hagedorn-Jensen micromethod . . . . .	75 to 105	Hawk and Bergeim (1937)
Folin's modification of Folin-Wu . . . . .	75 to 105	
Benedict's copper reduction . . . . .	70 to 100	
Somogyi-Shaffer-Hartman . . . . .	70 to 100	Glassberg (1931)
Somogyi-Shaffer-Hartman . . . . .	70 to 95	
Myer-Bailey (on 1000 subjects) . . . . .	60 to 160	
87.6 per cent of 1000 subjects . . . . .	70 to 120	John (1926)
75.2 per cent of 1000 subjects . . . . .	70 to 110	
Not stated (data for 431 subjects collected from the literature) . . . . .	40 to 160	Gray (1923)
90.7 per cent of 431 subjects . . . . .	70 to 120	
86.3 per cent of 431 subjects . . . . .	70 to 110	
Folin-Malmros (subjects all young women) . . . . .	86 to 101	Dionne and Arenstam (1930)
Not stated . . . . .	70 to 120	Peters and Van Slyke (1931)
Not stated . . . . .	70 to 120	Joslin (1937)

Rudesill and Henderson,<sup>5</sup> using the Folin-Wu method, made 288 blood sugar determinations on 144 nondiabetic children from two to fifteen years of age and found the fasting levels to range from 70 to 105 mg. per 100 ml. They state that "a review of the literature indicates that the range of normal blood sugar values in infants is probably 60 to 100 mg. per hundred cubic centimeter in most cases."

(Sugar tolerance tests are given in Chapter 18.)

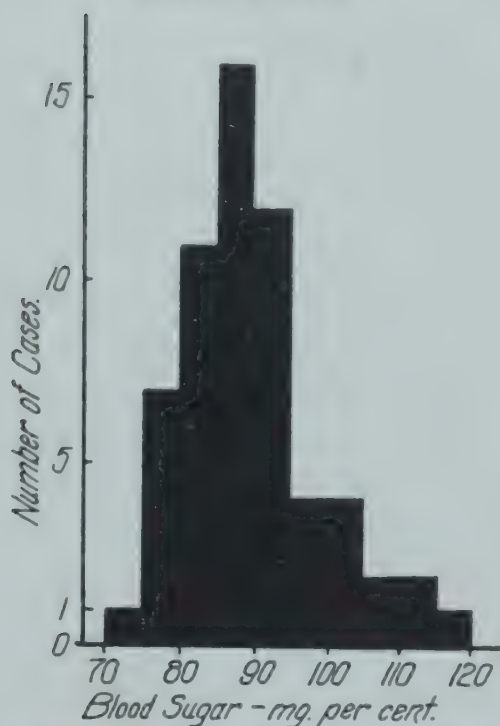


Fig. 42. Concentrations of sugar in the blood of 60 normal adults in the postabsorptive state. (Lozner, E. L., Winkler, A. W., Taylor, F. H. L., and Peters, J. P.: *J. Clin. Investigation*, vol. 20.)

Somogyi<sup>7</sup> has shown that the nonglucose reducing substances in blood are greater in cells than in serum. The range of nonglucose substances by the Miller-Hartmann method in whole blood was found to be 23 to 31 mg. equivalents of glucose per 100 ml.; in plasma, 7 to 13; and in corpuscles, 41 to 51. It would appear that glutathione and ergothioneine account in large measure for these nonglucose or "saccharoid" components.

Mosenthal and Berry<sup>8</sup> direct attention to adopting blood sugar methods that measure true sugar values. They found that with the commonly used Folin-Ciocalteu method the amount of nonglucose reducing substances in blood was highly constant and varied from 1 to 78 mg. per 100 ml. They also showed that values for arterial blood sugar exceeded the venous by 20 mg. per 100 ml. in 35 per cent of 200 determinations; in only 9 per cent were the values of venous blood sugar lower than the arterial.

In a study of the distribution of sugar between corpuscles and serum in twenty-six healthy adults, Somogyi<sup>9</sup> found that there was a nearly equal distribution when the calculations were made on the basis of total reducing substances. When calculations were based on true sugar values (obtained by yeast fermentation), the ratio of corpuscle to serum sugar averaged 0.77.

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## Chapter 15

### LIPIDS

LIPIDS OF THE blood and other tissues include (1) fats, triglycerides of oleic, stearic, palmitic acids and the like; (2) phospholipids, (3) cerebrosides; and (4) sterols (cholesterol and its esters and other sterols in small amounts).

The lipid content of various tissues differs widely, and in blood the lipids of the cells and of the plasma are quite dissimilar. Sinclair<sup>55</sup> distinguished between lipids that are structural, an integral part of the cell, and those that are metabolic in function. Probably a difference in function accounts for the contrast between plasma and blood cell lipids, and for the much greater significance of plasma or serum lipids in so far as the study of physiologic and pathologic states is concerned. Because of the disturbing effects of some anticoagulants, serum is preferred for analysis.

Dependable procedures for the analysis of serum lipids are still in process of development and, even when available, have not yet come into general use in clinical laboratories. Much of the earlier work dealing with lipids in blood and other tissues is of doubtful significance because of the defects in methods. Because of this, reference to work done before 1927 for the most part has been omitted.

The concentration of total lipid is measured less frequently than are the component fractions, and fewer data are available. Page and his co-workers<sup>56</sup> and Barker<sup>57</sup> studied large groups. Both found a wide range of values in plasma (see Table 66).

### CHOLESTEROL

By far the largest part of the work on serum lipids deals with cholesterol. The methods used differ considerably in principle, and the figures obtained by application of the several methods may vary. Precipitation of cholesterol by digitonin is generally regarded as the most specific procedure. This makes possible separation of the cholesterol from other lipids before measuring the amount of cholesterol by weighing, oxidation, colorimetry or turbidimetry. In most laboratories, however, the preliminary separation of cholesterol is omitted, and cholesterol is determined directly in the extracted lipids by treatment with acetic anhydride and sulfuric acid or zinc chloride.

There is considerable difference in the mean values reported by different workers. The lowest is that of Corcoran and Rabinowitch,<sup>58</sup> who found 141 mg. per 100 ml. in plasma; the highest, that of Page and his associates,<sup>56</sup> 232 mg. per 100 ml. of serum. The greater credence, other factors being equal, should be given to the figures derived from studies of large numbers of subjects. In those that included serum values for fifty or more subjects the average value

from 194 to 235 mg. per 100 ml. As shown by composite studies of over healthy subjects, *the average concentration of serum cholesterol is about 200 per 100 ml.* The results of colorimetric determinations, when suitable precautions are taken, are not significantly different from those of the methods using digitonin.<sup>58</sup>

### CHOLESTEROL ESTERS

The proportion of the total cholesterol in serum that is combined with fatty acids to form esters has been reported by most workers to average between 65 and 75 per cent. Only a few have found less than 50 per cent in healthy persons. Boyd,<sup>57</sup> who has made careful studies in this field, found a remarkably uniform relationship between free and esterified cholesterol, the latter remaining about 70 to 75 per cent of the total cholesterol despite wide variations in concentration of total cholesterol in serum.

### PHOSPHOLIPID

Average normal values of phospholipid concentrations range from 145 mg.<sup>35</sup> to 200 mg. per 100 ml.<sup>52</sup> The reason for the large variations is not clear. Table 67 shows the distribution of lipid phosphorus among lecithin, cephalin and sphingomyelin. There are large discrepancies; some workers have found lecithin predominant with little cephalin or sphingomyelin, while others have found the opposite. Improved methods have yielded little cephalin or sphingomyelin in serum. The amount of serine in the serum phospholipid is small.

### FATTY ACID

Wilson and Hansen<sup>67</sup> found the average molecular weight of the fatty acids of blood serum to be 290 in a group of seventeen subjects. The average iodine number was 108. The iodine number of the unsaponifiable fraction of blood lipids was 63.4, which is in good agreement for the value found for cholesterol, 65.7. The iodine number of serum fatty acids found by Boyd<sup>7</sup> in a larger group was 89, with values ranging from 65 to 112. Phospholipid fatty acids had more double bonds, the iodine number averaging 124. In connection with studies of the blood lipids in allergic states, Bloor, Blake and Bullen<sup>6</sup> have determined in a group of normal controls the following iodine numbers of the fatty acids: in neutral fat of serum, 102; in phospholipid, 125; in cholesterol esters, 158.

Oleic acid is the most abundant single fatty acid in serum, while palmitic acid is the most important of the saturated acids. Linoleic acid is present to the extent of 5 per cent, and arachidonic acid 3 per cent, of the total fatty acids.<sup>9</sup>

By direct measurement of glycerol concentrations, Blix<sup>8</sup> found 30 to 70 mg. per 100 ml. of neutral fat (triglyceride) in plasma. These values are lower than those calculated by difference (see Table 66), the usual method of arriving at an estimate of triglyceride.

TABLE 66  
CONCENTRATION OF LIPIDS IN BLOOD, PLASMA OR SERUM

Number of Subjects	Sex	Total Lipid (Mg./100 ML.)	Cholesterol			Phospholipid (Mg./100 ML.)	Neutral Fat (Mg./100 ML.)	Fluid; Method	Investigator
			Total (Mg./100 ML.)	Free (Mg./100 ML.)	Esterified (Percentage of Total)				
8	F		162 ± 32	47 ± 63	71	197 ± 23	154 ± 42	Plasma; oxidimetric	Boyd (1933, 1934, 1935)
8	F	582	177	52	71	185	131		
9	F	617 ± 75	181 ± 22	....	70 ± 6.4	195 ± 37	154 ± 77		
10	M		166	105	....	....	....	Blood; oxidimetric	Chaikoff et al. (1934)
2	F	539 (488-610)	(117-195)	(95-122)	....	....	....		
66	M	735 ± 216	232 ± 62	82 ± 17*	65	181 ± 71	225 ± 137	Plasma; oxidimetric	Page et al. (1935)
59	MF	....	210 (132-392)	....	73.1 ± 1.4	....	....	Serum; digitonin	Sperry (1936)
10		(100-198)	....	....	....	....	....	Colorimetric	Schube (1936)
7	MF	507 (357-627)	141 (93-222)	....	68 (57-66)	124 (47-223)	176 (25-348)	Plasma; oxidimetric	Corcoran and Ra- binowitch (1937)
19	MF	572 (437-765)	141 (96-209)	....	66 (52-77)	178 (68-337)	190 (58-368)		
16	F		(118-249)	....	(67-77)	....	....	Serum; digitonin colorimetric	Offenkrantz (1938)
167	F		(147-322)	....	69	....	....	Serum; digitonin Blood; digitonin	Muhlbeck and Kaufman (1938)
167	F		(135-258)	....	46	....	....		
47	MF	....	210 (110-320)	....	....	....	....	Serum; colorimetric	Reinhold (1938)

200	568 (365-919)	218 (135-370)				Plasma; colorimetric Barker 1939
51.....	....	(141-404)	(31-310)	72 (61-84)		Serum; digitonin colorimetric Pickhardt et al. (1939)
174.....	MF	194 ± 35.6 (107-320)	..	72 (68-76)	3.12 ± 1.49 mEq.	Serum; digitonin (1943) Peters and Man
118.....	M	196	..	....		Blood; colorimetric Kountz et al. (1945)
94.....	F	237	....	....		
212.....	MF	214	..	....		
20.....	..	(160-267)	(41-73)	(71-77)		Serum; digitonin Sobel and Mayer (1945)
35.....	..	(120-300)	(30-79)	(73.9-1.9)		Serum; digitonin Clarke and Marney (1945)
20.....	MF	186 ± 26	..	68 ± 6	232 ± 28	Plasma; colorimetric Foldes and Murphy (1946)
25.....	..	173 ± 49	64 ± 24	63.5		Plasma; colorimetric Hess 1937

Method refers to the procedure for determination of cholesterol.

Figures in parentheses are ranges; those preceded by ± are standard deviations.

\* A later paper from the same laboratory states that these results are high by 2 per cent (Folch, Schneider and Van Slyke, 1940).

## LIPIDS OF THE CELLS

The lipids of the blood corpuscles (Table 68) show important differences from the serum lipids. The red blood cells contain somewhat less total lipid than does serum. One remarkable difference is the absence or near absence of cholesterol ester. On the other hand, phospholipid concentrations are higher in the cells; free cholesterol and neutral fat are lower than in serum.

The white blood cells are rich in lipid, the high concentrations of phospholipid being particularly noteworthy (Table 68).

TABLE 67  
PHOSPHOLIPIDS OF BLOOD

<i>Number of Subjects</i>	<i>Total† Phospholipid</i>	<i>Lecithin (Mg./100 ML.)</i>	<i>Cephalin</i>	<i>Sphingomyelin</i>	<i>Tissue</i>	<i>Investigator</i>
350.....	210 (120-320)	....	....	....	....	Feigl (1918)
20.....	145	19	68	58	Plasma	Kirk (1938)
20.....	196	32	117	51	R.B.C.	
6.....	226	107	96	23	Serum	Thannhauser et al. (1939)
4.....	189	99	55	35	Plasma	Erickson et al. (1940)
12.....	185 (168-212)	145* (128-169)	40 (9.5-78)	.... ....	Plasma	Brante (1940)
12.....	280	33	65	186	Blood	Ramsey and Stewart (1941)
16.....	240 (179-278)	....	<5%	....	Plasma	Taurog et al. (1944)
	197†	131*	42	....	Serum	Artom (1945)
8.....	220	174	13	33	Plasma	Hack (1947)

\* Total choline-containing phospholipid.

† Includes about 6 per cent serine-containing phospholipid.

‡ Lipid phosphorus  $\times 25$ .

## LIPIDS IN INFANTS AND CHILDREN

At birth, concentrations of lipids in plasma are low. Sperry<sup>37</sup> and Muhlbock and Kaufman<sup>41</sup> found concentrations of serum cholesterol in the newborn well below those of adults; a rapid rise occurred, however, within the first three or four days of life. Sperry reports a sharp upward trend during the next twenty-five days until values characteristic of childhood were attained. Esterified cholesterol varied widely during the neonatal period, with values lower, proportionately, than those found in adults.

From one month upwards Hodges, Sperry and Anderson<sup>32</sup> found values for serum cholesterol almost identical with those of adults, in a group of 417 children. Again, esterified cholesterol was slightly lower and showed more variation in the children than in adults.

TABLE 68  
LIPIDS OF BLOOD CORPUSCLES

Number	Sex	Total Lipid	Cholesterol		Phospholipid	Neutral Fat	Investigator
			Total	Esterified			
			Mg./100 Ml.				
	F	...	Red Blood Cells 210 (190-240)	...	440 (390-480)	10 (0-30)	Bloor (1916)
	M	...	190 (170-230)	...	400 (350-440)	70 (0-150)	
	F	598 ± 62	140 ± 32	16 ± 9	361 ± 56	93 ± 42	Boyd (1934)
	M	594 ± 123	133 ± 62	16 ± 21	366 ± 155	89 ± 80	
	MF	349*	115*	16.5%	233*	44*	Erickson et al. (1937)
	M	...	139 (126 ± 150)	0	...	....	Brun (1939)
	F	...	140.8 (133 ± 149)	1%			
	F	1710 ± 734	White Blood Cells 300 ± 60	110 ± 97	802 ± 255	536 ± 536	Boyd (1933)

\* Multiplying by  $10^{-12}$  gives concentration in average single red blood cell.

### LIPIDS RELATIVE TO AGE

Studies of serum lipids of elderly persons are less extensive than are those of children. Blix<sup>3</sup> and Page and his co-workers,<sup>18</sup> in a comprehensive and careful study, observed no significant difference in elderly persons, either in serum cholesterol or other lipids. Hunt<sup>33</sup> also could detect no correlation with advancing age. Ohmer, Abignolli and Cheyron<sup>15</sup> have described a trend toward lower serum cholesterol values in the very old. Thus it appears that there is no distinctive change in serum lipids that can be attributed to an age effect except for that in the first days of life.

### LIPIDS DURING MENSTRUATION

Menstruation is said to influence the concentration of cholesterol and other lipids in blood. Elevated values are reported to precede menstruation.

Chauffard<sup>14</sup> found that the elevation persisted throughout the period of menstruation, while other observers noted that cholesterol decreased just before menstruation, with falling values reaching a minimum at the end of the menstrual period.

### LIPIDS DURING PREGNANCY

Pregnancy is accompanied by a rise in serum lipid concentrations. Usually the rise begins in the first trimester with a rise in serum phospholipid, followed by a rise in cholesterol concentration. Neutral fat also increases sharply. In some patients the rise in serum lipids occurs much later in the course of pregnancy, sometimes as late as the eighth month.

### DAILY AND SEASONAL VARIATIONS

Whether the concentration of blood cholesterol remains stable in a given person during the day has been a source of controversy. Some observers have reported that large fluctuations occurred within the space of a few hours.<sup>38-40</sup> Most investigators have found variations to be insignificant<sup>7, 11, 37, 41</sup> in so far as the usual clinical applications of cholesterol determinations are concerned.

Cholesterol concentrations in blood or serum may remain remarkably constant for long periods. Gardner and Gainsborough<sup>23</sup> observed little change in a subject studied periodically during three years, the largest deviation from the mean being 15 per cent. Schube<sup>54</sup> found during a four-month period that the concentration of blood cholesterol varied from the mean by 30 to 90 mg per 100 ml. in persons studied at weekly intervals. Man and Gildea<sup>39</sup> made studies extending over four years. The difference between highest and lowest values in certain subjects of their group of ten was as much as 30 per cent and as little as 1 per cent. Variations in men and women were the same. In a group of ten patients studied for a year, Turner and Steiner<sup>64</sup> found variations ranging from 4 to 15 per cent.

### LIPIDS RELATIVE TO BODY BUILD

Mjassnikow,<sup>40</sup> Tschernorutsky,<sup>63</sup> Petersen<sup>50</sup> and Gildea, Kahn and Man<sup>4</sup> investigated the relationship of body build to blood lipid concentrations. Persons of stocky build had higher concentrations of cholesterol and other lipids in blood or serum than did those of slender build. Sperry<sup>57</sup> did not find such a correlation in his study of normal persons. Bruger and Poindexter,<sup>58</sup> Hetényi<sup>29</sup> and Peters and Man<sup>49</sup> failed to find any difference in serum lipid concentrations between obese adults or children and those that were normally nourished.

### INFLUENCE OF FAT INGESTION ON LIPIDS

After ingestion of a meal containing appreciable amounts of fat, a significant increase in the concentration of neutral fat in serum occurs. For example, Man and Gildea<sup>39</sup> reported an average increase of 62 per cent in concentration of fatty acid other than that in phospholipid when fat was ingested to the extent of 3.5 to 4 gm. per kilogram of body weight. The response of phospholipids

was found to be variable; Wilson and Hanner<sup>50</sup> reported that only three of seven men showed an increase. Corcoran and Rabinowitch<sup>51</sup> actually found a decrease in phospholipid and esterified cholesterol after soya bean oil administered. Ingestion of fat in more moderate amounts also causes a decrease in concentration of serum fatty acid of at least 20 per cent, while the increase in phospholipid averages 10 per cent.<sup>26, 39, 42</sup>

Most investigators have found little or no effect on concentration of cholesterol in blood or serum caused by ingestion of fat.<sup>18, 21, 34, 35, 40, 47, 55</sup>

## INFLUENCE OF FASTING ON LIPIDS

Fasting for two days does not significantly affect serum cholesterol concentration, according to Kartin and his associates.<sup>54</sup> Starvation for longer periods, however, caused a rise in serum cholesterol concentration averaging 13 mg. per 100 ml. Lipid phosphorus rose also, although the rise was significant in only one-third of the subjects. Administration of glucose prevented a rise in serum lipid. Sunderman<sup>60</sup> reported a striking increase in esterified cholesterol of serum in a man who fasted forty days. Other lipids showed no marked alterations.

It has long been known that when the concentrations of serum total lipid are elevated, all the principal components almost always share the increase. Similarly, low total lipid is likely to be the result of a general lowering of the concentrations of the several components. The relative contributions of the principal lipid fractions vary, however, as shown by the work of Page and his associates,<sup>58</sup> who found that with increasing concentrations of total lipid in fasting men, neutral fat and phospholipid accounted for most of the increase. Cholesterol, although it increased, did so to a smaller extent.

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## Chapter 16

# HEMOGLOBIN, PORPHYRINS AND RELATED COMPOUNDS

### TOTAL HEMOGLOBIN

(See Chap. 6, p. 37)

TOTAL HEMOGLOBIN indicates the sum of all the forms of hemoglobin in the blood. Under ordinary conditions, reduced and oxygenated hemoglobin are the only forms present in significant amounts.

Since the work of Haldane and Smith<sup>11</sup> in 1900, the oxygen-combining capacity of hemoglobin has been adopted as one of the standards of measuring hemoglobin content. These workers, from a study of twelve normal adult subjects, concluded that the average amount of hemoglobin in 100 ml. of blood combined with 18.5 ml. of oxygen at 0° C. and 760 mm. pressure. Later workers<sup>10, 19, 25</sup> indicated this value to be higher—about 20.9 ml. of oxygen. By Hüfner's factor of 1.34 volumes per cent of oxygen for combining with each gram of oxyhemoglobin, 20.9 volumes per cent oxygen capacity represents  $\frac{20.9}{1.34} = 15.6$  gm. of hemoglobin per 100 ml. of blood. )

The measurements of human hemoglobin in the past depended on assumed constants obtained from data on the hemoglobin of other species. These constants were 1.34 ml. of oxygen capacity per gram of hemoglobin and 0.335 per cent iron. Bernhart and Skeggs<sup>2</sup> measured the iron concentration of dried human crystalline hemoglobin from a composite sample of erythrocytes from twenty adults. They obtained an average value of 0.340 per cent iron, corresponding to a minimal molecular weight for hemoglobin of 16,400 and an oxygen capacity of 1.36 ml. per gram. These values suggest that the constants for hemoglobin assumed in the various hemoglobin methods are 1.5 per cent too low and that the concentrations reported as grams of hemoglobin per 100 ml. of blood are 1.5 per cent too high.

*Oxygen capacity* of blood denotes the total amount of oxygen (expressed as volumes of O<sub>2</sub> under standard conditions) which can be carried by hemoglobin in 100 ml. of blood. *Oxygen content* denotes the total amount of oxygen (expressed as volumes of O<sub>2</sub> under standard conditions) which is contained in 100 ml. of blood, as it is withdrawn. Blood for oxygen content is collected and stored under oil or over mercury) so that oxygen is neither added nor lost. Oxygen values for normal human blood are given in Table 73 (p. 129).

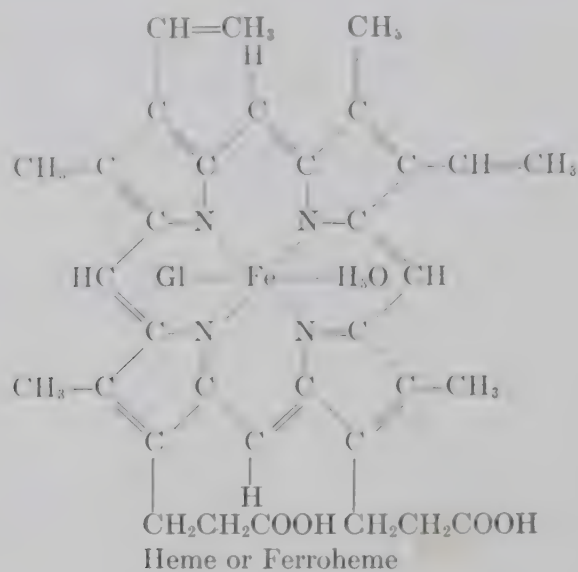
### TYPES OF HEMOGLOBIN AND RELATED COMPOUNDS

The hemoglobin derivatives present in man are oxyhemoglobin, reduced hemoglobin,\* carboxyhemoglobin, methemoglobin (ferrihemoglobin, inactive

\* Oxyhemoglobin and reduced hemoglobin values are discussed in Section II

hemoglobin, myoglobin, verdohemoglobin, methemalbumin, choleglobin and sulfhemoglobin.

Figure 43 gives structural formulas of the iron complexes of protoporphyrin (see also Fig. 44).<sup>7</sup>



<i>Divalent Iron Complexes</i>	<i>Radicals on Iron Atom</i>	<i>Corresponding Chromoproteins</i>
Heme (ferroheme, protoheme IX)	$  \begin{array}{c}  \text{N} \quad \text{N} \\  \diagdown \quad \diagup \\  \text{Protein} \cdots \text{Fe} \cdots \text{H}_2\text{O} \\  \diagup \quad \diagdown \\  \text{N} \quad \text{N}  \end{array}  $	Hemoglobin (ferrohemoglobin), myoglobin, erythrocrucorin, heliocorubin, actiniohematin
Oxyheme (oxyferroheme)	$  \begin{array}{c}  \text{N} \quad \text{N} \\  \diagdown \quad \diagup \\  \text{Protein} \cdots \text{Fe} \cdots \text{O}_2 \\  \diagup \quad \diagdown \\  \text{N} \quad \text{N}  \end{array}  $	Oxyhemoglobin, and oxidized forms of other pigments listed above
Carbonylheme (carbonylferroheme)	$  \begin{array}{c}  \text{N} \quad \text{N} \\  \diagdown \quad \diagup \\  \text{Protein} \cdots \text{Fe} \cdots \text{CO} \\  \diagup \quad \diagdown \\  \text{N} \quad \text{N}  \end{array}  $	Carbonylhemoglobin (carbon monoxide hemoglobin)
Sulfoheme (?)	Structure not known, contains =S radical	Sulfhemoglobin
<i>Trivalent Iron Complexes</i>		
Metheme (hematin, ferriheme hydroxide, protoferriheme IX)	$  \begin{array}{c}  \text{N} \quad \text{N} \\  \diagdown \quad \diagup \\  \text{Protein} \cdots \text{Fe} \cdots \text{OH} \\  \diagup \quad \diagdown \\  \text{N} \quad \text{N}  \end{array}  $	Methemoglobin (ferrihemoglobin), catalase, peroxidases
Hemin (ferriheme chloride)	$  \begin{array}{c}  \text{N} \quad \text{N} \\  \diagdown \quad \diagup \\  \text{Protein} \cdots \text{Fe} \cdots \text{Cl} \\  \diagup \quad \diagdown \\  \text{N} \quad \text{N}  \end{array}  $	

Fig. 43. Structural formulas for hemoglobin compounds. — indicates primary valence, and . . . ., secondary valence. Everett, M. R.: Medical Biochemistry, Paul B. Hoeber, Inc.

# ABSORPTION SPECTRA OF HEMOGLOBIN AND ITS RELATED COMPOUNDS

Table 69 shows the absorption bands of hemoglobin and its related compounds.

TABLE 69  
ABSORPTION BANDS OF HEMOGLOBIN AND RELATED COMPOUNDS

Compound	Wavelength (Millimicrons)						
	Infra-Red		Visible				Ultraviolet
Hemoglobin (Brooks, 1941).....	840	710	640.2				
Best and Taylor, 1945).....	...	...	...	576.9	544.8	514	413
Reduced hemoglobin (Best and Taylor, 1945).....	...	...	565				
Carboxyhemoglobin (Best and Taylor, 1945).....	...	...	570.9	535			
Hemoglobin (Brooks, 1941).....	850	710					
Best and Taylor, 1945).....	...	...	634	578	540	500	
Holden, 1943).....							407
Hemoglobin (Bywater et al., 1941)							
Oxy.....	581						
Carboxy.....	579						
Met.....	636						
Rossi, 1940)							
Oxy.....	...	...	542	418			
Carboxy.....	...	...	540	428			
Deoxyhemoglobin (Holden, 1936)							
Oxy.....			610	590	...	...	410
Reduced.....			624				
Carboxy.....			620				
Human albumin (Fairley, 1940).....	...	...	623-624	540	500		
Deoxyhemoglobin (Lemberg, 1941).....			655				
Reduced.....			628-630				
Carboxy.....			628-630				
Hemoglobin (Best and Taylor, 1946).....	...	...	618	578	540		

## CARBOXYHEMOGLOBIN

(Carbon Monoxide Hemoglobin)

Under ideal conditons no carboxyhemoglobin is present in normal human blood.\* Under average normal conditions of living, however, there is a slight concentration of this pigment in the blood.

TABLE 70

CARBOXYHEMOGLOBIN (CARBON MONOXIDE HEMOGLOBIN) CONCENTRATION IN  
NORMAL HUMAN BLOOD\*(Gettler and Mattice, 1933)<sup>9</sup>

<i>Type of Person</i>	<i>Number of Persons</i>	<i>Average Concentration as Volume CO/100 Ml. in Blood</i>	<i>Range</i>
New York City dwellers.....	18	0.27	0.00-0.84
Country dwellers.....	12	0.24	0.09-0.64
Taxi drivers.....	2 (5 deter- minations)	3.40	1.47-4.33
City street workers.....	12	0.69	0.25-1.44

\* Method used: gasometric technic of Van Slyke (1927).

Pace and his co-workers<sup>20</sup> reported on the carboxyhemoglobin concentration of thirty-two healthy men between the ages of eighteen and forty-two years, members of the U. S. Navy. Measurements were made as volume per cent carbon monoxide<sup>16</sup> and converted to per cent carboxyhemoglobin. The values are as follows:

Mean: 3.4 per cent carboxyhemoglobin  
Standard deviation: plus or minus 2.4 per cent  
Range: 0.0 to 8.9 per cent carboxyhemoglobin

Everett<sup>7</sup> indicates that the normal concentration of carbon monoxide in the blood is 0.15 plus or minus 0.05 volume per 100 ml. of blood.

METHEMOGLOBIN (FERRIHEMOGLOBIN, INACTIVE  
HEMOGLOBIN)

The results of analyses of normal blood for methemoglobin are given in Table 71.

Measurements of the methemoglobin concentrations in the blood may be made by gasometric and colorimetric methods.

The *gasometric method* for measuring methemoglobin (inactive hemoglobin) requires two determinations, one for active hemoglobin and another for total hemoglobin. Active hemoglobin (ferrohemoglobin), which combines reversibly with carbon monoxide or oxygen, is measured by determining the carbon monoxide or oxygen-binding power of an untreated sample of whole blood. The concentration of *total hemoglobin* in the sample is measured by de-

mining the carbon monoxide or oxygen binding power of the blood sample after treatment with sodium hyposulfite, which reduces any inactive hemoglobin (ferri-compounds) present to active reduced hemoglobin (ferrohemo-  
globin). The concentration of *inactive hemoglobin* represents the difference between the total hemoglobin and the active hemoglobin. Titanous tartrate has also been used as a reducing agent (Ramsey, 1944). With the *colorimetric method* a spectrophotometer is used to measure quantitatively potassium

TABLE 71  
NORMAL BLOOD CONCENTRATIONS OF METHEMOGLOBIN AND INACTIVE HEMOGLOBIN  
(Van Slyke et al, 1946)

Number of Subjects	Method Used	Inactive Hemoglobin			Author
		Per cent of Total Hemoglobin			
		Minimum	Maximum	Mean	
.....	Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub> + CO gasometric	0	12.0	3.0	Ammundsen (1937, 1939, 1941)
.....	Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub> + CO gasometric	-1.2	1.2	-0.2	Kollner (1942)
.....	Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub> + CO gasometric	0.7	5.0	2.8	Roughton, Darling and Rost (1944)
.....	Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub> + CO gasometric	-1.5	0.5	-0.5	Kollner (1945)
.....	Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub> + CO gasometric				
.....	Immediate	0.6	1.8	1.3	Van Slyke et al. (1946)
.....	Na <sub>2</sub> S <sub>2</sub> O <sub>4</sub> + CO gasometric				
.....	Two hour	0.0	1.1	0.4	
.....	Ti <sup>+++</sup> + O <sub>2</sub> gasometric	-0.5	7.0	1.9	Ramsay (1944)
Methemoglobin					
.....	KCN photometric		8		Havemann et al. (1939)
.....	KCN photometric	1.1	2.4	1.7	Schmid-Burgk (1940), quoted by Heubner
.....	KCN photometric	0.1	0.8	0.4	Paul and Kemp (1940)
.....	KCN photometric				
.....	Immediate	0.0	1.1	0.4	Van Slyke et al. (1946)
.....	KCN photometric				
.....	Two hour	0.0	1.5	0.4	.

The same blood samples were analyzed immediately upon withdrawal from the vein, and again after standing for 2 hours at room temperature.

anide derivatives of methemoglobin. The assumption that the concentration of inactive hemoglobin is equal to the methemoglobin concentration has been questioned by Van Slyke et al., 1946 (see Table 71).

Van Slyke and his colleagues,<sup>23</sup> using both the gasometric and the colorimetric procedures, analyzed normal human blood. One set of measurements was made immediately on withdrawal of the specimen. A second set was made after the blood had stood for two hours at room temperature (see Table 71). The mean methemoglobin concentration by the colorimetric method was 0.4 per cent of the total hemoglobin. One-half of the results were from 0.0 to 0.3 per cent, which is within the limit of error of the measurement. There was no

change in this value in twenty-four hours. The mean inactive hemoglobin concentration immediately after withdrawal of blood, determined by the gasometric carbon monoxide method, was 1.3 plus or minus 0.35 per cent of the total hemoglobin. Two hours later the average value of the inactive hemoglobin had fallen to the level of the colorimetric methemoglobin determinations.

### MYOGLOBIN OR MYOHEMOGLOBIN

Myoglobin is one of the normal respiratory pigments of muscle tissue. It is similar to hemoglobin in the following ways: (1) It forms a reversible combination with carbon monoxide and oxygen. (2) It has the prosthetic group, ferroheme, which contains protoporphyrin-9 Type III. (3) It is changeable to the met-compound.

Myoglobin differs from hemoglobin, as shown in Table 72.

TABLE 72

	<i>Myoglobin</i>	<i>Hemoglobin</i>
Molecular weight (Svedberg, 1938) . . . . .	17,000	68,000
Fe atoms/molecule (Svedberg, 1938) . . . . .	1	4
Alpha absorption band (Millikan, 1937) . . . . .	581 m $\mu$ .	577 m $\mu$ .
Renal threshold (Yuile and Clark, 1941) . . . . .	20 mg. 100 ml.	100 mg. 100 ml.

Renal clearance of myoglobin is 25 times greater than that of hemoglobin.

The concentration of myoglobin in the various muscles is not constant. With cytochrome, it is present in all muscle tissue in approximately inverse proportions.<sup>15</sup>

Bywaters and Stead<sup>6</sup> report that human muscle contains about 500 mg. of myoglobin (estimated as hemoglobin) per 100 gm. of wet muscle.

### VERDOHEMOGLOBIN OR GREEN HEMOGLOBIN

According to Watson,<sup>24</sup> the first step in the change of hemoglobin to bilirubin is not the splitting off of the iron atoms, but rather the opening of the protoporphyrin ring between the number I and II pyrrole groups (see Fig. 44) and the removal of the methene bridge at that point. The resulting compound is verdohemoglobin.

Barkan and Walker<sup>1</sup> report that the iron of verdohemoglobin is more easily split off than the iron of hemoglobin. In normal persons he finds that 5 per cent of the circulating blood pigment has this easily split-off iron.

Havemann,<sup>13</sup> using a direct method for measuring verdohemoglobin, observes that in normal persons 8 per cent of the total hemoglobin is in the form of verdohemoglobin.

### METHEMALBUMIN

Methemalbumin is the combination of free hematin and albumin. Fairley<sup>2</sup> has shown that when hematin occurs in the blood stream it is always in combination with the albumin molecule as methemalbumin, and never alone.

Methemalbumin is not normally present in the blood,<sup>21</sup> except at birth, which time Haselhorst and Papiendieck<sup>12</sup> and Hellmuth<sup>13</sup> found in umbilical blood a substance which they describe as hematin.

TABLE 73

OXYGEN VALUES IN NORMAL HUMAN BLOOD (RESTING INDIVIDUALS) (See page 123)

Determination	Sample of Blood	Subjects	Number of Determinations	Range of Values	Mean	Standard Deviation	Investigator
Oxygen content vol. %	Arterial	Men	50	17.3-22.3	19.6	1.2	Gibbs et al. (1942)
Oxygen capacity vol. %	Arterial	Men	50	18.4-23.9	20.9	1.3	Gibbs et al. (1942)
Oxygen saturation %	Arterial	Men	50	91.2-95.8	93.9	1.0	Gibbs et al. (1942)
Oxygen content vol. %	Venous (jugular blood)	Men	50	11.0-16.1	12.6	1.3	Gibbs et al. (1942)
Oxygen capacity vol. %	Venous (jugular blood)	Men	50	18.4-23.9	20.8	1.3	Gibbs et al. (1942)
Oxygen saturation %	Venous (jugular blood)	Men	50	55.3-70.7	61.8	3.7	Gibbs et al. (1942)
Oxygen content vol. %	Arterial	..	..	15-23	..	..	Hawk et al. (1947)
Oxygen content vol. %	Venous	..	..	10-18	..	..	Hawk et al. (1947)
Oxygen capacity vol. %	Arterial or venous	..	..	16-24	..	..	Hawk et al. (1947)
Oxygen saturation %	Arterial	Normal adults	25	....	94.5	..	Cullen & Cook (1942)
Oxygen saturation %	Arterial	..	..	95-97	..	..	Roughton and Darling (1944)

The oxygen capacity of blood will follow the normal variation in hemoglobin concentration, which is dependent in the normal person upon the percentage of red blood cells.

## PORPHYRINS

**STRUCTURE.** The basic unit of porphyrin structure is the pyrrole ring containing one nitrogen and four carbon atoms. Four pyrrole rings (I-IV) connected in a ring by four methene bridges (alpha-delta) form the porphyrin unit common to all porphyrins (Fig. 44). On the porphyrin structure are eight replaceable hydrogen atoms for which, in the forming of different porphyrin compounds, are substituted methyl, ethyl, vinyl,  $\text{CH}_2\text{CH}_2\text{COOH}$  or  $\text{COOH}$  groups.

All porphyrins found in nature have a basic structure related to one or another of two synthetic isomers, prepared by Fischer and Orth<sup>22</sup> (Fig. 44), porphyrin Type I or Type III. Etioporphyrin Type I has four methyl groups in positions 1, 3, 5, 7 and four ethyl groups in positions 2, 4, 6, 8. Etioporphyrin Type III differs only in that on the number IV pyrrole ring the methyl group is in the number 8 position with the ethyl group in the number 7 position.

The isomeric coproporphyrins Types I and III have four methyl and four  $\text{CH}_2\text{CH}_2\text{COOH}$  groups and are directly changed to the respective etioporphyrin type by decarboxylation of the  $\text{CH}_2\text{CH}_2\text{COOH}$  radical to form the ethyl group (Fig. 44). The two isomeric uroporphyrins Types I and III have

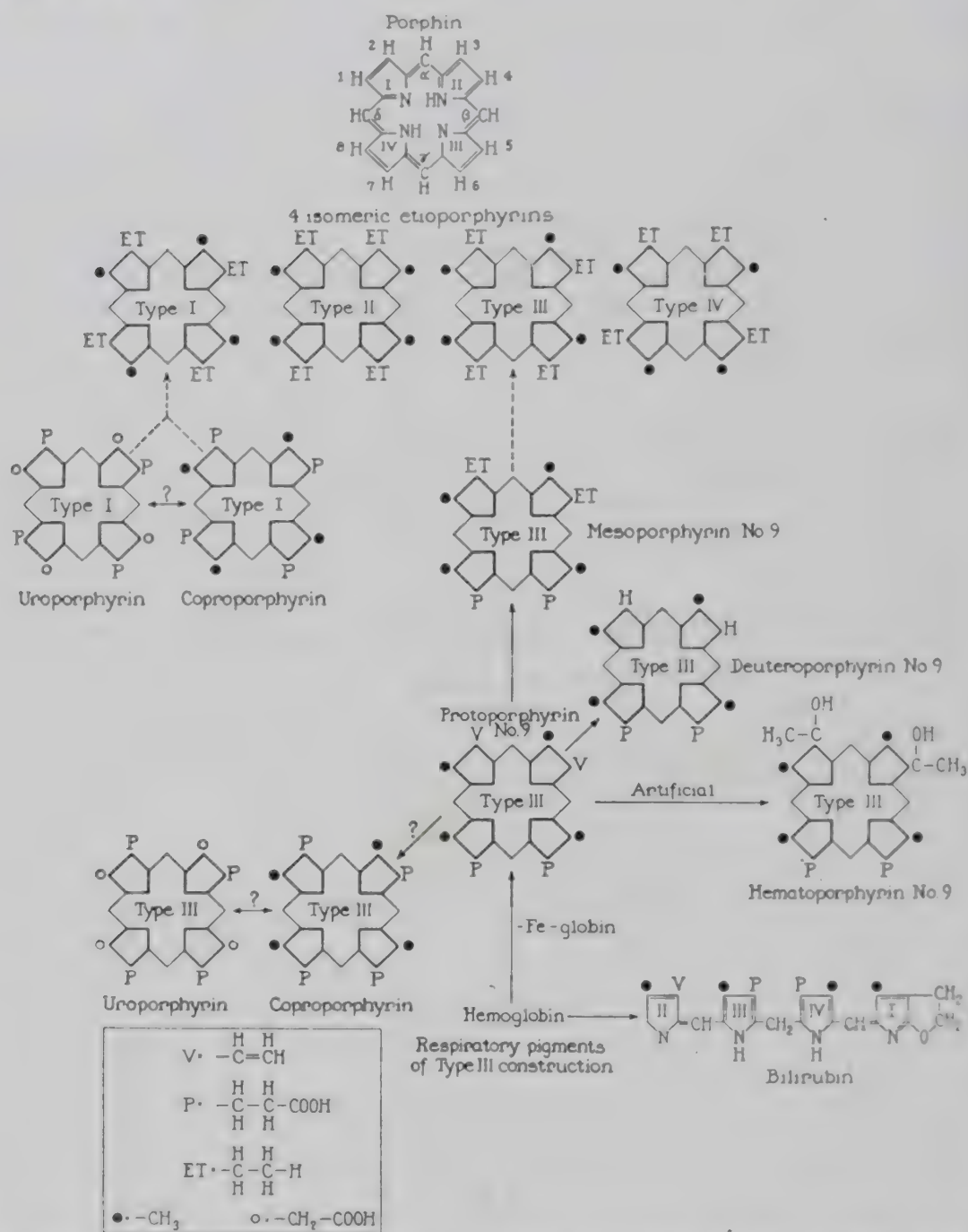


Fig. 44. Structural formulas of the porphyrins. (Dobriner, K., and Rhoads, C. P.: *Physiol. Rev.*, vol. 20.)

four  $\text{CH}_2\text{COOH}$  and four  $\text{CH}_2\text{CH}_2\text{COOH}$  groups and may be converted to the corresponding coproporphyrin type by decarboxylation of the  $\text{CH}_2\text{COOH}$  groups and then by further decarboxylation to the respective etioporphyrin type.

All naturally occurring porphyrins with three types of substituting radicals

respond in basic structure to etioporphyrin Type III, and also to the number 9 isomer of the fifteen isomeric Type III mesoporphyrins. Therefore these compounds are designated as Type III, number 9 compounds (Fig. 44). The number 9 compounds have in common four methyl groups in positions 1, 3, 5 and 8; and two  $\text{CH}_2\text{CH}_2\text{COOH}$  groups in positions 6 and 7; they differ only in the radical in the 2, 4 positions (Fig. 44).

Mesoporphyrin-9 Type III (synthetic, and naturally occurring in feces) . . . . .	2, 4, ethyl
Protoporphyrin-9 Type III (natural in hemoglobin and myoglobin) . . . . .	2, 4, vinyl
Hematoporphyrin-9 Type III (artificially prepared from hemoglobin) . . . . .	2, 4, $\text{COHCH}_3$
Deuteroporphyrin-9 Type III (natural in feces after hemoglobin or myoglobin digestion) . . . . .	2, 4, hydrogen

Protoporphyrin-9 is transformed to mesoporphyrin-9 by hydrogenation of the vinyl radicals to form, in positions 2 and 4, ethyl radicals (Fig. 44).

Mesoporphyrin-9 becomes etioporphyrin Type III by decarboxylation of  $\text{CH}_2\text{CH}_2\text{COOH}$  groups in positions 6 and 7 to ethyl groups.

Hematoporphyrin-9 is produced from protoporphyrin-9 by adding one ether molecule to each of the vinyl radicals in positions 2 and 4.<sup>54</sup>

Deuteroporphyrin-9 can be prepared from protoporphyrin-9 by reducing position 2, 4 vinyl groups and replacing them with hydrogen atoms.

PHYSICAL CONSTANTS. Table 74 lists physical constants which aid in identifying the porphyrins and their isomers.

TABLE 74  
PHYSICAL CONSTANTS OF IMPORTANT PORPHYRINS  
(Dobriner and Rhoads, 1940)<sup>35</sup>

	HCl No.*		Melting Points of Methyl Ester	Solubility of Free Porphyrin in NaOH
	Free Porphyrin	Methyl Ester		
Etioporphyrin-9 . . . . .	2.0	5.5	228	Insoluble
Mesoporphyrin-9 . . . . .	0.5	2.5	216	Insoluble
Deuteroporphyrin-9 . . . . .	0.4	2.0	223	Insoluble
Hematoporphyrin-9 . . . . .	0.1	...	212	Insoluble
Protoporphyrin I . . . . .	0.08	1.5	252	Soluble
Protoporphyrin III . . . . .	0.09	1.5	{ 135† 170	Soluble
Etioporphyrin I . . . . .	...	7 ca	302	Soluble
Protoporphyrin III . . . . .	...	7 ca	256	Soluble
Deuteroporphyrin I . . . . .	...	3	400-405	
Deuteroporphyrin III . . . . .	...	...	360-363	

\* The concentration of hydrochloric acid which will remove two-thirds of the porphyrin from an ether solution of the porphyrin when equal volumes are shaken together.

† Double melting point.

ABSORPTION SPECTRA. Also of help in porphyrin identification are the absorption spectra (Table 75). The Type I and III isomers of the respective porphyrin compounds have identical absorption bands.

In the ultraviolet spectral region the porphyrins absorb from 360 to 400 millimicrons. Wavelengths from 300 to 450 millimicrons and, to some extent up to 650 millimicrons produce porphyrin photosensitization effect.<sup>54</sup>

TABLE 75  
ABSORPTION SPECTRA OF IMPORTANT PORPHYRINS  
(Kirstahler, 1941)<sup>49</sup>

		Wavelength in Millimicrons						
		I	II	III	IV	V	VI	VII
Protoporphyrin . . . . .	Acid	602.4	582.2	557.2				
	Ether	632.5	604.5	585.1	575.8	536.8	501.9	
Hematoporphyrin . . . . .	Acid	593.1	572.4	548.7	524.8	508.7		
	Ether	623.3	596.6	578.3	576.6	528.6	494.9	
Deuteroporphyrin . . . . .	Acid	592.4	572.6	549.3				
	Ether	610.8	595.7	576.8	566.8	557.7	525.9	494.1
Uroporphyrin I, III . . . . .	Acid	597.9	577.6	553.6	526.6	511.3		
Coproporphyrin I, III . . . . .	Acid	593.9	574.6	550.9				
	Ether	623.9	597.3	577.7	568.2	529.3	497.9	
Mesoporphyrin . . . . .	Acid	593.1	572.4	548.7	524.8	508.7		
	Ether	623.3	596.6	578.3	576.6	528.6	494.9	

Acid = 25 per cent hydrochloric acid.

FLUORESCENCE SPECTRA. The optimum fluorescence of porphyrin compounds is at a *pH* well over 7.

TABLE 76  
FLUORESCENCE SPECTRA OF THE PORPHYRIN SUBSTANCES  
(From DeMent, 1945)<sup>34</sup>

Substance (in HCl Solution)	Fluorescence Spectrum Wave- lengths in Millimicrons
Coproporphyrin-I and III . . . . .	659-645, 601-589
Protoporphyrin-9 III . . . . .	663-647, 609-598
Mesoporphyrin-9 III . . . . .	657-642, 599-588
Uroporphyrin I and III . . . . .	660-645, 601-592
Hematoporphyrin-9 III . . . . .	654-646, 602-592
Etioporphyrin I and III . . . . .	656-641, 598-589
Porphine . . . . .	Maxima 648, 604

Recently Schwartz and his co-workers<sup>55</sup> quantitatively separated the Type I and Type III coproporphyrin isomers by measuring the fluorescence of a mixture of the two in 30 per cent acetone, before and after cooling at 4° C. At 4° C. the coproporphyrin-I precipitates rapidly and the residual fluorescence is almost entirely due to the nonprecipitated coproporphyrin III.

Conant and Kamerling<sup>33</sup> found that the absorption bands shifted toward shorter wavelengths at the temperature of liquid air. Klüber<sup>34</sup> reports that the coproporphyrin fluorescent emission bands also shift toward the blue at  $-195^{\circ}\text{C}$ . The principal fluorescent emission band of coproporphyrin in ether shifts 60 mμ from units toward the shorter wavelengths at the temperature of liquid oxygen.

COPROPORPHYRIN I

Coproporphyrin I is normally present in the bile,<sup>35-37</sup> in amniotic fluid,<sup>38, 40</sup> meconium<sup>33, 68</sup> and in fetal serum during the last month of pregnancy and at birth.<sup>36</sup>

Coproporphyrin is not a normal constituent of the serum,<sup>57</sup> and there is no increase in coproporphyrin excretion during normal pregnancy.<sup>32, 36, 46</sup> Children appear to excrete less coproporphyrin than do adults.<sup>35</sup>

TABLE 77  
DAILY URINARY AND FECAL EXCRETION OF COPROPORPHYRIN I

<i>Urinary 24-Hours Micrograms</i>	<i>Fecal 25-Hours Micrograms</i>	<i>Total Excretion</i>	<i>Ratio</i>	<i>Method</i>	<i>Investigator</i>
.....	145-250	150-300	0.2-0.6	Fluorometric	Brugsch (1934, 1936)
.....	.....	.....	.....	.....	Carrie (1936)
20.....	191-274	226-376	0.17-0.6	Photoelectric	Dobriner and Rhoads (1940)
0.....	.....	...	...	Fluorometric	Franke and Fikentscher (1935)
000.....	.....	...	...	Fluorometric	Van den Bergh and Grotepass (1932)
00.....	150-350	160-450	...	.....	Jope and O'Brien (1943)
0.....	.....	.....	.....	Colorimetric	Lageder (1934)
50.....	150-285	200-435	0.3-0.6	.....	Localio et al. (1941)
.....	.....	...	...	Photofluorometric	Nesbitt and Snell (1942)
85.5.....	300-400	...	0.07-0.24	Photofluorometric	Mason and Nesbitt (1944)
10.....	.....	...	...	Fluorometric	Thiel and Kammerer (1933-1934)
10.....	.....	...	...	Fluorometric	Tropp and Siegler (1937)
0.....	.....	...	...	Fluorometric	Vannotti and Neuhaus (1935)
.....	.....	...	...	Fluorometric	Vigliani and Sonzini (1938)
00.....	.....	...	...	Gravimetric	Watson (1937)
-80.....	.....	...	...	Fluorometric	Watson and Larson (1947)

COPROPORPHYRIN III

Coproporphyrin III is present in the urine in small amounts.<sup>37, 40, 71</sup> Watson and Larson (1947) report values from 1.4 to 34.3 micrograms in twenty-four hour collections of urine from forty-one normal persons.<sup>71</sup> It has not been isolated in the feces, but the melting points (Table 74) reported for fecal porphyrins suggest that traces of this substance may be present.<sup>69</sup>

## PROTOPORPHYRIN-9, TYPE III

Protoporphyrin-9, Type III is the porphyrin present in hemoglobin and myoglobin.

*Normal blood values are as follows:*

*8 to 12 micrograms per 100 ml. of blood<sup>57</sup>*

*12 to 15 micrograms per 100 ml. of blood<sup>63</sup>*

*19.7 to 40.7 micrograms per 100 ml. of erythrocytes<sup>72</sup>*

*13 to 140 micrograms per 100 ml. of erythrocytes (mean, 35).<sup>68</sup>*

On a meat-free dietary regimen only traces of protoporphyrin are found in the feces.<sup>28</sup> If the subject is on a diet containing myoglobin or hemoglobin, 2.8 per cent of the ingested porphyrin is recovered as protoporphyrin-9, Type III, and 89.5 per cent as protohemin.<sup>45</sup>

Protoporphyrin is present in normal bone marrow<sup>29, 60</sup> and also in reticulocytes.<sup>71</sup> No protoporphyrin is present in the bile.<sup>66</sup>

## DEUTEROPORPHYRIN-9, TYPE III

With a normal person on a meat-free diet, Schumm,<sup>56</sup> Snapper and Van Crevald<sup>59</sup> and Boas<sup>28</sup> found that there was no deuteroporphyrin present in the feces. According to Watson,<sup>70</sup> however, small amounts of deuteroporphyrin-9, Type III are found. After the ingestion of myoglobin or hemoglobin 0.9 per cent of the ingested porphyrin is excreted as deuteroporphyrin, and 6.6 per cent as deuterohemin.<sup>45</sup>

## MESOPORPHYRIN-9, TYPE III

Zeile and Rau<sup>73</sup> and Grotepass and Defalque<sup>43</sup> isolated mesoporphyrin-9, Type III in the feces in small amounts.

## UROPORPHYRIN TYPE I

Uroporphyrin Type I is never found in the excretions of normal persons. It is found, however, with congenital porphyria.<sup>42</sup>

## UROPORPHYRIN TYPE III

This, too, is not found in the excretions of normal persons, but occurs only in the excretions of those with acute porphyria.

## HEMATOPORPHYRIN-9, TYPE III

Hematoporphyrin-9, Type III is artificially produced from hemoglobin.<sup>84</sup>

## PORPHOBILIN

According to Waldenström and Vahlquist,<sup>69</sup> porphobilin is probably a dipyrromethene. It is always associated with acute porphyria and is never found in the excretions of normal persons.

## PENTDYOPENT

Pentdyopent is a red compound found chiefly in pathologic urine (especially in hemolytic jaundice and liver disease) which has been treated with sodium sulfate. The principal absorption band begins at 525 millimicrons (hence the

and extends to 540 millimicrons.<sup>27, 47</sup> Bingold<sup>27</sup> found pentdyopent in al erythrocytes. Fischer and Muller<sup>48</sup> identified this compound as a romethene.

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## Chapter 17

### BLOOD VITAMINS

TABLE 78 GIVES the normal concentration of vitamins in the blood. No tests are available for detecting vitamins D or K in the blood. The nomenclature and unit equivalent are given in Chapter 71 and included in Table 394. The requirements for adults and children recommended by the National Research Council are given in Chapter 71.\*

TABLE 78

#### NORMAL VALUES OF BLOOD VITAMINS

<i>Vitamin</i>	<i>Amount</i>
A (2100 persons):	
Int. units/100 ml. of serum . . . . .	10-245 (mean 86) <sup>9</sup> 35-40 <sup>11</sup>
Carotenoids (2100 persons):	
Gamma/100 ml. of serum . . . . .	6-312 (mean 94) <sup>9</sup>
B <sub>1</sub> —Thiamine:	
Gamma/100 ml. of blood . . . . .	7.5 <sup>2</sup> 7.5 ± 2 <sup>3</sup>
Gamma/100 ml. of plasma . . . . .	0.07-0.88 <sup>7</sup> 0.5 <sup>2</sup>
B <sub>2</sub> —Riboflavin (600 persons):	
Gamma/100 ml. of blood . . . . .	13-85 (mean 27) <sup>9</sup> 45 <sup>3</sup>
Niacin:	
Mg./100 ml. of blood . . . . .	0.52-0.83 <sup>8</sup>
Mg./100 ml. of blood cells . . . . .	1.2-1.5
Mg./100 ml. of plasma . . . . .	0.03 <sup>5</sup>
Biotin:	
Micrograms/100 ml. of blood . . . . .	0.07-0.10 <sup>12</sup>
Pantothenic acid:	
Micrograms per 100 ml. of blood . . . . .	18-35 <sup>10</sup>
C—Ascorbic acid:	
Mg./100 ml. of plasma . . . . .	0.7-1.5 <sup>4</sup> 0.75-2.42 <sup>1</sup>
Children . . . . .	0-1.7
Adults . . . . .	
Saturated state (adults) <sup>2</sup>	
Blood . . . . .	1.5
Plasma . . . . .	1.7
Erythrocytes . . . . .	0.8
Leukocytes and platelets . . . . .	22.0
E—Alpha-tocopherol:	
Mg./100 ml. of serum . . . . .	1.1 ± 0.5
Adults . . . . .	0.9 ± 0.2 <sup>6</sup>
Children . . . . .	0.6-1.4 mg. <sup>8</sup>
dl Alpha-tocopherol serum . . . . .	

\* For the vitamin content of sweat and urine, see pages 363 and 488.

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## Chapter 18

### TOLERANCE TESTS

#### GLUCOSE TOLERANCE

**DOSE ORAL GLUCOSE TOLERANCE TEST.** After a 100 gm. dose of glucose is ingested, the maximum glucose concentration of venous blood in normal subjects should be reached within thirty to sixty minutes.<sup>34</sup> The maximum blood

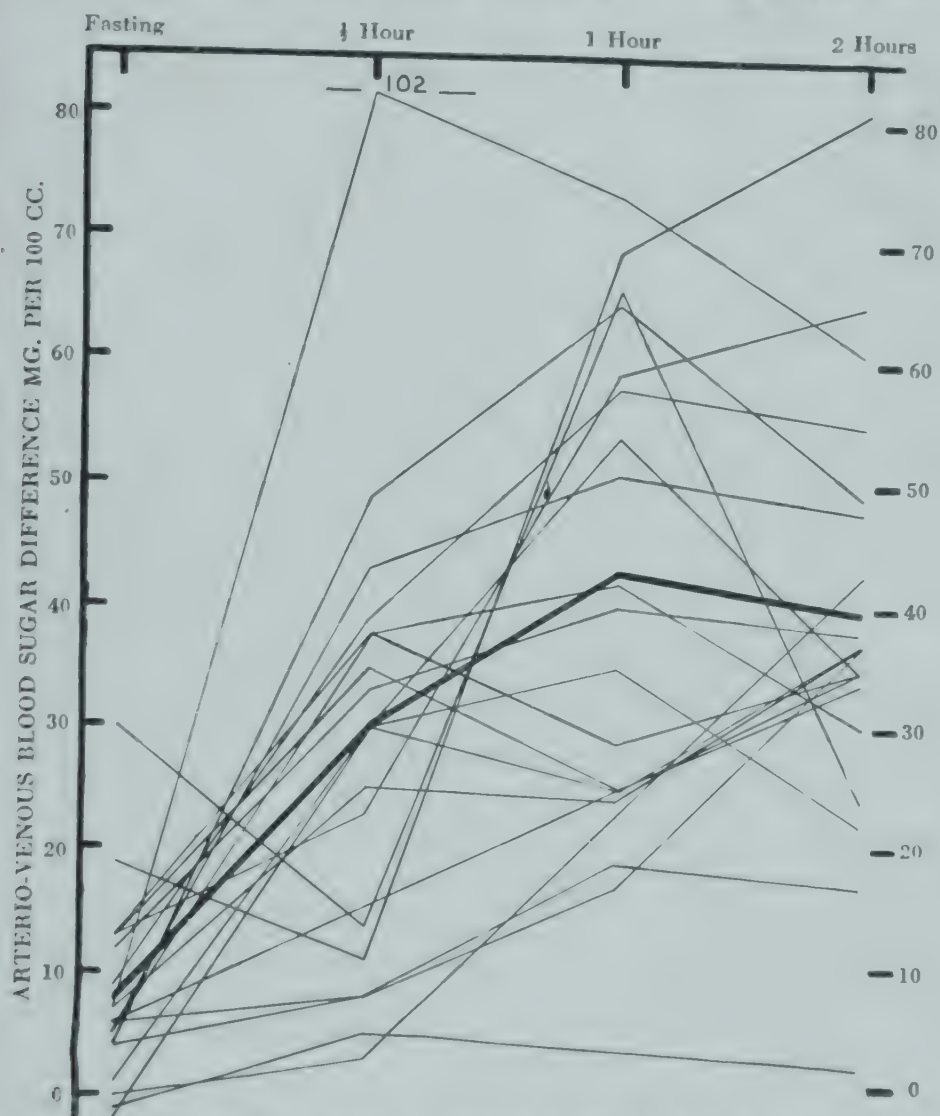


Fig. 45. Arteriovenous blood sugar difference after 100 gm. of glucose. The marked rise in arteriovenous blood sugar difference after the taking of glucose is evident. The average difference (heavy line) is 8 mg. per 100 cc. fasting, and 40 mg. 2 hours after glucose ingestion. (M. Mosenthal, H. O.: M. Clin. North America, vol. 31.)

level is usually not over 140 mg. per 100 ml., although values as high as 160 mg. per 100 ml. are considered within the normal range. Mosenthal<sup>37</sup> adds that the concentration of venous blood sugar should return to 120 mg. per 100 ml. within twenty minutes after the peak value is reached.

Hale-White and Payne's<sup>13</sup> results indicate that adult tolerance to glucose decreases as age advances. According to Mosenthal,<sup>17</sup> moreover, elderly subjects have a maximum value of venous blood glucose not over 190 mg. per 100 ml., and the concentration should decrease to 140 to 150 mg. per 100 ml. within 120 minutes.

The glucose tolerance is likely to be increased if the test is repeated more than once every five days.<sup>26</sup> Less marked change is observed with longer intervals between the tests.<sup>14</sup>

Two factors help to confuse the comparison of results of glucose tolerance tests: (a) the difference in sugar concentration between arterial or capillary and venous blood (Fig. 45) and (b) the varying amounts of nonglucose-reduc-

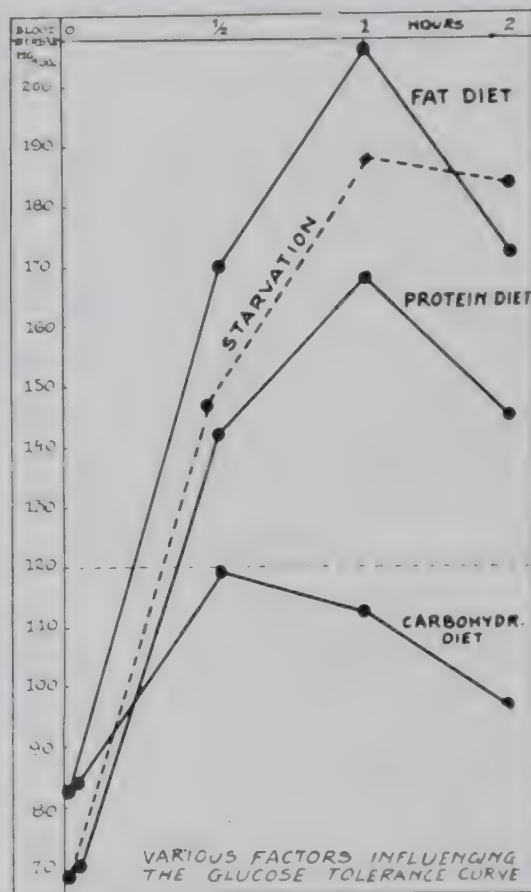


Fig. 46. Factors influencing the glucose tolerance curve. (John, H. J.: *Endocrinology*, vol. 15.

substances, the concentration of which in the blood ranges from 10 to 30 mg. per 100 ml., according to the method used.

Conn<sup>27</sup> investigated dietary factors influencing glucose tolerance and found no significant change in normal or underweight persons after a high carbohydrate diet. After a low carbohydrate diet, however, both groups showed decreased glucose tolerance, with impairment somewhat greater in the undernourished. Carbohydrate restriction yielded higher concentrations of blood sugar, after ingestion of glucose, in women than in men. Andrews and Meuth<sup>28</sup> found decreased glucose tolerance after a high fat diet, increased tolerance after a high carbohydrate diet, and moderately decreased tolerance after a high fat, low carbohydrate diet plus insulin. Figure 46 shows the effect of previous diets on the 100 gm. glucose tolerance test.

Glucose in Whole Blood—Mg. per 100 <i>Ml.</i>										
Subjects	Amount of Glucose Ingested—Gm.	Source of Blood	Time in Minutes after Ingesting Glucose						Method of Sugar Analysis	Investigator
			0	30	60	90	120	180		
10	100	Arterial Mean Venous Mean	100 90	120 112	140 125	.. ..	129 110	118 105	..	Blotner (1945)
35	100	Venous Mean Range	90 (75-105)	138 (85-175)	136 (78-230)	.. ..	109 (70-170)	92 ..	Folin and Malmros (1929)	Freeman et al. 1942
6	100	Capillary Venous Mean	86 85	148 122	119 95	.. ..	113 94	78 73	Miller and Van Slyke (1936)	Rymer and Ravin (1941)
	100	Capillary Mean	92	167	158	..	60	90	Folin and Svedburg (1930)	Albright (1941)
3	30 gm./sq. meter of body surface	Mean Range Capillary	89 (82-96)	136 (104-171)	142 (114-160)	114 (95-150)	81 (72-93)	..	.....	Flaum (1938)
4	100	Venous Mean Range	87 (75-100)	139 (121-160)	132 (113-156)	.. ..	107 (80-133)	74 (44-103)	Folin-Wu	Ralli and Shannon (1931)
300	100	Not given Mean Range	90 (40-160)	140 (60-230)	120 (40-280)	.. ..	110 (30-260)	90 (40-170)	Not given	Gray (1923)
	50	Capillary Range	70-120	100-200	..	70-120	..	..	..	Lawrence 1947
6	50	Capillary Venous Mean	87 87	148 126	140 115	.. ..	91 82	77 76	Miller and Van Slyke (1936)	Rymer and Ravin (1941)

TABLE 79A GLUCOSE TOLERANCE TESTS IN PREGNANT WOMEN

Subjects	Dose of Glucose (Gm.)	Source of Blood	Glucose in Whole Blood in Mg./100 ml. of Whole Blood								Method of Analysis	Investigator
			Time in Minutes After Ingestion of Glucose									
			0	15	30	60	90	120	150	180		
51 pregnant women	100 gm.	Not given	90 (50-110)	..	140 (100-180)	140 (60-250)	..	120 (40-210)	..	130 (90-240)	Not given	Gray (1923)
50 normal women	100 gm.	Mean	91	137	152	146	139	122	115	108	Hagedorn-Jenson	Williams and Wills (1928)
14 pregnant women (1-5 months)	100 gm.	Mean Range	85 81-99	127 (107-145)	152 (122-179)	162 (120-188)	148 (111-179)	136 (89-179)	116 (67-152)	107 (63-125)	Hagedorn-Jenson	Williams and Wills (1928)
40 pregnant women (5-9 months)	100 gm.	Mean Range	94 69-116	124 (71-161)	152 (94-203)	153 (114-202)	152 (98-208)	134 (81-174)	128 (98-205)	120 (81-152)	Hagedorn-Jenson	Williams and Wills (1928)
21 women post partum.	100 gm.	Mean Range	96 72-129	142 (94-197)	165 (116-185)	152 (107-238)	144 (115-222)	131 (94-213)	119 (88-204)	114 (90-208)	Hagedorn-Jenson	Williams and Wills (1928)
Time in Minutes after Ingestion of Glucose												
11 normal women	50 ml. 50% solution of glucose	Venous	0	5	15	30	60	120	Urine sugar		Benedict	Johnson and Bonsnes (1948)
			82 (70-92)	265 (187-354)	193 (111-247)	153 (58-207)	112 (58-160)	75 (60-91)	6	8		
20 pregnant women	50 ml. 50% solution of glucose	Mean	77 65-94	241 (191-315)	175 (124-224)	126 (76-164)	85 (54-109)	73 (50-84)	7	2	Benedict	Johnson and Bonsnes (1948)

Pregnant women subjected to oral glucose tolerance tests have a rise in glucose similar to that in normal adults, but the return to normal is pro-  
d (see Table 79a).<sup>17a</sup>

In children, as the dose of glucose increases, the blood glucose curve rises. Normal maximum rise in the concentration of capillary blood is within the  
of 160 to 180 mg. per 100 ml. in thirty to sixty minutes. The blood glucose  
returns to the fasting value within 180 minutes. A preparatory diet high in  
causes a high, prolonged blood glucose curve.<sup>30</sup> Obese children show litt  
endency to abnormal glucose tolerance.<sup>26</sup>

Table 79 presents a summary of the work of twelve investigators. The  
blood glucose values fall within the stated limits; however, the range of  
num and minimum values is great in normal adults.

TABLE 80

ONE HOUR TWO-DOSE GLUCOSE TOLERANCE TEST (EXTON ROSE)\*

Subjects	Source of Blood		Glucose in Whole Blood Mg./100 Ml.			Method	Investigator
			Time in Minutes				
			0	30	60		
0% weight	Venous	Mean	93	144	126	Folin-Wu	Wayburn and Gray (1942)
		Standard error	2	6	5		
		Standard deviation	8	23	20		
er 30% weight	Venous	Mean	95	149	140		
		Standard error	2	4	8		
		Standard deviation	8	16	24		
	Venous	Mean	85	126	115	Folin-Wu	Mathews, McGath and Berkson (1939)
		Range	63-110	79-176	54-179		
	Capillary	Mean	107	162	156	Alkaline ferri- cyanide	Exton and Rose (1931)
		Range	85-133	116-235	116-215		
dren	Venous	Mean	94	125	132	Folin micro- method	Blatt, Kern and Korteum (1945)
		Range	70-130	90-161	102-183		
	Saliva	Mean	10	36	52	Korteum(1941)	
		Range	3-27	6-124	6-175		

\* 50 gm. doses, one at 0 minutes, the other at 30 minutes, for adults; children received two 12.5 gm. doses.

EXTON-ROSE ONE-HOUR TWO-DOSE GLUCOSE TOLERANCE TEST. Accord-  
to Exton and Rose,<sup>12</sup> the following criteria are normal: (1) fasting blood  
sugar within usual limits; (2) at thirty minutes a rise in the concentration of  
blood sugar not over 75 mg. per 100 ml.; (3) at sixty minutes a blood sugar  
which does not exceed the thirty minute value by more than 5 mg. per  
100 ml.; (4) urine samples sugar-free. In addition, Gould and his co-workers<sup>16</sup>  
stated that (1) the fasting blood sugar should be less than 120 mg. per 100 ml.,  
(2) the thirty minute blood sugar level less than 50 mg. above the fasting value,  
(3) the sixty minute level less than 30 mg. per 100 ml. greater than the  
thirty minute value. A normal person has a blood sugar concentration at sixty  
minutes below 154 mg. per 100 ml., which value is usually lower than or equal  
to the thirty minute level.<sup>26</sup> Obesity definitely impairs a person's ability to

TABLE 81  
INTRAVENOUS GLUCOSE TOLERANCE TEST

Subjects	Dose of Glucose (Gm.)	Injection Interval (Minutes)	Source of Blood		Glucose in Whole Blood in Mg./100 Ml.								Method of Glucose Analysis	Investigator
					Time in Minutes									
					0	15	30	45	60	90	120	180		
65	0.2/Kg. of body wgt.	1 5	...	Mean Range	80 50-120	112 70-125	...	...	...	...	...	...	Folin-Wu	McKean et al.(1935)
10*	0.5/Kg. of body wgt. as 20% solution	25 ml. per min.	Capillary	Mean Range	86 61 98	240 202 282	176 139 205	137 94 167	100 77 127	76 59 84	...	...	Hagedorn- Jensen (1923)	Crawford (1938)*
12 children	27 6	3	Capillary	Range	...	161-250	99 190	75-140	64-102	67-102	...	...	Harrison (1937)	Tunbridge and Alli- bone (1940)
60	25	2	Venous	Mean Range	89 72 117	193 144 234	138 74 215	105 53-165	97 58-151	82 57-107	79 65-90	75 67-81	Benedict (1926)	Lozner et al. (1941)
				Standard deviation	9.1	24	31	26	23	11	7	5		

\*Adapted.

re the strain of this two-dose glucose tolerance test, whereas the previous carbohydrate intake does not influence the glucose tolerance as measured by method (Table 80).<sup>47</sup> In children one to four years old the mean saliva glucose concentration follows the mean concentration of blood glucose during modified Exton-Rose glucose tolerance test, but there is no constant blood glucose; saliva sugar ratio (see Table 80).<sup>6</sup>

**INTRAVENOUS GLUCOSE TOLERANCE TEST.** The maximum concentration of blood glucose is of second importance in the definition of normality in this test, whereas the time interval required for the glucose concentration to return to the fasting level is considered the most constant and valuable criterion of normality. *The commonly accepted maximum interval is 120 minutes.* Height and duration of the blood glucose curve vary with the dose of glucose and the rate of injection.<sup>36, 45, 55, 56</sup> With a constant dose of glucose, weight, height, sex and previous ingestion of food do not affect the height or duration of the blood glucose curve. Elderly persons and those ingesting a high fat, low carbohydrate diet show decreased tolerance to intravenous glucose.<sup>56</sup> The high level of glucose tolerance in childhood decreases at about ten to thirteen years of age to the adult level.<sup>9</sup> Tests repeated at fourteen-day intervals are almost identical.

## INSULIN, GLUCOSE-INSULIN, INSULIN-ADRENALIN AND ADRENALIN TOLERANCE TESTS

*The normal insulin tolerance curve shows decreased blood sugar concentration at thirty minutes and increased blood sugar concentration at sixty to one hundred minutes.* According to Albright and his co-workers,<sup>1</sup> *the normal blood glucose curve during the glucose-insulin tolerance test should be flat, with insulin and glucose balancing each other. The normal adrenalin tolerance test curve shows an increase in blood glucose concentration at sixty minutes to a level of 50 to 60 mg. per 100 ml. above the fasting value (see Table 82).*

## GALACTOSE TOLERANCE

**ORAL GALACTOSE TOLERANCE TEST.** *The normal excretion of galactose in urine is less than 3 gm. during a period of two to five hours after the oral administration of 40 gm. of galactose (Table 83).<sup>1, 28, 41, 49</sup> The normal blood galactose concentration rises after a test dose of galactose to a maximum level within thirty to sixty minutes and returns to normal in 120 minutes. The normal range of the maximum blood galactose concentration is wide. Both maximum height and duration of blood galactose curve increase with increasing doses of galactose.<sup>5, 20</sup> Age has little effect on the galactose tolerance.<sup>44</sup> After an intravenous dose of galactose the normal person completely clears the blood of galactose in seventy-five minutes (Table 84).<sup>3, 24, 27</sup>*

## GLYCEROL TOLERANCE TEST

*Normal subjects after a dose of 80 gm. of glycerol have a maximum rise in the concentration of blood glucose in 120 minutes (see Table 85).<sup>59</sup>*

TABLE 82  
INSULIN, GLUCOSE INSULIN, INSULIN-ADRENALIN AND ADRENALIN TOLERANCE TESTS

Glucose in Whole Blood in Mg./100 ml.															
Test	Subjects	Dosage	Source of Blood	Time in Minutes									Method	Investigator	
				0	15	30	45	60	90 v	120	150	180			
Insulin tolerance test	Adults <sup>1</sup>	Insulin: 0.1 unit/kg. of body wgt. I.V.		Mean	100*	47*	48*	67*	78*	94*	115*			McLean	Albright (1941)
	12 children (2-22 months) <sup>10</sup>	Insulin: 0.25 units/kg. of body wgt.		Mean Range	73 58-95	.....	55 39-78	47+ 21-63	49 27-62	.....	46 20-67				Daniel (1941)
Glucose-insulin tolerance test	16 <sup>11</sup>	Insulin: 5 units I.V. Glucose: 60 gm. orally	Capillary					Flat blood glucose curve							De Wesselow and Griffiths (1938)
	3 males <sup>1</sup>	Insulin: 5 units I.V. Glucose: 30 gm./sq. meter of body surface	Capillary	Mean Range	94 90-100	91+ 86-95	84 73-95	.....	87 83-92	80 72-90				Hagedorn-Jensen	Flaum (1938)
	9 children (1.5-2 years) <sup>10</sup>	Glucose: 3 gm/kg. of body wgt. orally Glucose: as above Insulin: 0.25 unit/kg. of body wgt. subcut.		Mean and S.D.	86 ± 2	.....	132 ± 5	.....	170 ± 4	.....	128 ± 6	.....	87 ± 5		Livingsstone and Bridge (1942)
				Mean and S.D.	84 ± 3	.....	117 ± 7	.....	125 ± 5	.....	84 ± 3	.....	80 ± 2		
Insulin-adrenalin tolerance test	20 <sup>4</sup>	Insulin: 0.1 unit/kg. of body wgt. at 0 minutes Adrenalin: 0.01 ml. (1-1000)/kg. of body wgt. at 120 minutes	Venous	Mean Range	87 70-100	.....	29 19-40	.....	61 38-80	75 55-95	79 58-92	105 76-170	132 85-192	Folin-Wu	Freeman et al. (1943)
Adrenalin tolerance test	10 children <sup>10</sup>	Adrenalin: 0.03 ml. kg. of body wgt.		Mean and S.D.	80 ± 3	.....	123 ± 4	.....	143 ± 5	.....	104 ± 8		76 ± 2		Livingsstone and Bridge (1942)

<sup>1</sup> Percentage of fasting glucose concentration.

## LACTIC ACID TOLERANCE TEST

Normal persons, after a 75 mg. dose of sodium d-lactate intravenously, show a maximum concentration of blood lactic acid in five minutes and a return to a 5 mg. per 100 ml. of the fasting blood lactic acid level in thirty minutes.<sup>51, 52</sup>

## LEVULOSE TOLERANCE TEST

The maximum blood levulose concentration in normal subjects ranges from 1 mg. per 100 ml., and the maximum rise above the fasting value ranges from 5 mg. per 100 ml. (see Table 86).

TABLE 83

## URINARY EXCRETION AFTER ORAL DOSES OF GALACTOSE\*

(Harding and van Nostrand, 1930)<sup>21</sup>

Subjects	Dose (Gm.)		Time in Minutes			
			60	120	180	Total
males .....	20	Average Range	100 36-302	Urinary galactose mg. /100 ml. 91 0-264	0 —	
les .....	20	Average Range	71 27-390	14 0-34	1 0-5	
males .....	30	Average Range	476 141-812	441 54-827	5 0-5	
les .....	30	Average Range	313 132-720	49 0-106	0 —	
males .....	50	Average Range	256 139-373	2118 346-3495	270 9-531	2644 394-4026
les .....	50	Average Range	970 68-2907	967 39-3689	79 9-65	2016 181-6820

Method: Harding and Downs (1929).

## SUCROSE TOLERANCE TEST

There is little difference in the average blood glucose curve when sucrose glucose tolerance tests are run parallel with equal doses of each sugar (Table 87).<sup>18, 47</sup>

## FAT TOLERANCE TEST

After a fatty test meal normal persons show a flat blood cholesterol concentration; normal thin persons have a flat decreasing curve; and normal obese persons a prolonged serum cholesterol elevation (see Table 88).<sup>7</sup>

TABLE 84

GALACTOSE TOLERANCE TESTS  
Oral Galactose Tolerance Test

Galactose in Whole Blood in Mg./100 ml.													
Subjects	Dose of Galactose (Gm.)		Time in Minutes								Method	Investigator	
			0	15	30	45	60	90	120	180			
12.....	50	Mean Range	....	....	....	....	38 0-102	....	....	12 0-51	1 0-2	Schaeffer-Hartman	Harding and van Nostrand (1930)
5 Women.....	1 kg. of body wgt.	Mean Range	8* 7-11*	....	61 28-90	....	....	99 67-120	64 27-118	....	....	Somogyi (1927) Benedict (1931)	Roe and Schwartzman (1932)
5 Men.....	11 kg. of body wgt.	Mean Range	8* 7-10*	....	44 29-67	....	....	68 37-138	46 30-101	....	....		
16 Adults.....	40	Mean Range	....	9 0-20	21 0-62	24 0-65	19 0-70	2 0-12	2 0-12	1 0-8	....	Schaeffer-Hartman	Harding and Grant (1933)
6 Men.....	80	Mean Range	....	....	39 10-62	51 8-102	58 12-95	31 10-48	31 10-48	15 2-19	2 0-4		
20 Men.....	40	Mean Range	....	....	18 0-39	....	....	26 2-63	10 0-37	5 0-18		Harding et al. (1933)	MacLagan and Rundle (1940)
27 Women.....	40	Mean Range	....	....	22 0-73	....	....	27 3-81	13 3-78	8 0-33			

Intravenous Galactose Tolerance Test

10.....	30 ml. of 50% solution	Mean Range	....	21.5 8-51	....	....				Somogyi	Jankelson and Leimer (1934)
15.....	1 ml. of 50% solution	Mean Range	....	....	....	....	0† 0-0†			Raymond and Blanco (1938)	Bassett et al (1940)
17.....	30 ml. of a 50% solution	Mean Range	....	176† 100-307	....	....		0-10			Kemp and Allen (1942)

\* Reducible by a nonfermentable reducing substance.

## FAT AND NITROGEN TOLERANCE TEST

the normal three-day response to the Schmidt test diet<sup>47</sup> is absorption of 92 per cent of ingested fat and 92 per cent of ingested protein; thus 6 per cent of

TABLE 85

## GLYCEROL TOLERANCE TESTS IN 13 NORMAL PERSONS

(From Wishnofsky et al., 1940)<sup>59</sup>

	Blood Glucose — Mg./100 Ml.			
	Time in Minutes			
	0	45	120	180
.....	97	104	116	106
.....	86-110	80-134	87-147	84-125

ose: 80 gm. orally.

ce of blood: venous.

TABLE 86

## LEVULOSE TOLERANCE

Subjects	Blood Source	Levulose in Whole Blood Mg./100 Ml.								Method	Investigator
			Time in Minutes								
			0	30	60	90	120	Max- imum Level	Maxi- mum Rise		
			3-7*					6-21	3-15		Herbert and Dawson (1938)
	Venous	Rise above normal			15		6-10		15	Diphenyl- amine	Herbert (1939-1940)
40 years	Venous	Mean Range		11 4-18	11 6-16	8* 4-12	4 1-11		12.8 (5-18)		Stewart, Scar- borough and Davidson (1938)
50 years	Venous	Mean Range		10 5-23	9 5-16	9 4-15	7 3-16			Patterson (1935)	

ose or oxalate accounts for the fasting levulose values. The normal fasting levulose concentration is 0. The  
levulose is 50 mg. orally.

ed fat and 8 per cent of ingested protein appear in the feces. The diet  
as 100 to 200 gm. of protein, 110 to 139 gm. of fat and 180 to 190 gm.  
bohydrate.

## BILIRUBIN TOLERANCE TEST

able 89 shows the results in normal persons after intravenous bilirubin  
istration.

TABLE 87  
SUCROSE TOLERANCE TEST

Subjects	Dosage	Mean Glucose Concentration in Whole Blood—Mg./100 ML.												Investigator			
		Time in Minutes															
		0	2	5	10	15	30	45	60	90	120	150	180				
26*	Glucose, 1.5/kg. of body weight	95	99	108	125	134	155	....									Haldi and Wynn (1947)
	Sucrose, 1.5/kg. of body weight	95	100	107	122	134	148	....									
18	Glucose, 75 gm.	101	...	...	...	...		....	146	...	117				98		Schmidt, Eastland and Burns (1935)
	Sucrose, 75 gm.	100	...	...	...	...		....	129	...	102				95		
58 Children	Sucrose	...	...	...	...	...		....	...	...	...				125†		Oppel and Federow (1928)
50 Men	Sucrose, 100 gm.	83-10	...	...	...	...		123 ± 24		89 ± 17	78 ± 15	77 ± 12					O'Brien and Higgins (1947)
60 Women	Sucrose, 100 gm.	78-10	...	...	...	...		110 ± 19		84 ± 18	77 ± 15	73 ± 12					

\* Somogyi method used.  
† Top normal value.

## TOLERANCE TESTS

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TABLE 88

## FAT TOLERANCE TEST\*

(Blotner, 1935)\*

Subjects		Plasma Cholesterol Concentration in Mg./100 Ml.				
		Time in Hours				
		0	2	4	6	8
Normal persons . . . . .	Mean	199	207	206	199	195
	Range	189-240	171-240	167-246	161-240	156-234
Normal thin persons . . . . .	Mean	199	200	195	190	185
	Range	152-267	141-272	139-259	145-250	128-237
Normal thin persons† . . . . .	Mean	201	217	222	212	195
	Range	164-225	177-257	166-264	160-260	161-228
Normal obese persons . . . . .	Mean	232	259	265	266	242

Test dose, 100 gm. of fat.

Test dose plus insulin.

TABLE 89

## BILIRUBIN TOLERANCE TEST

(Normal Results)

Subjects	Dose of Bilirubin IV	Normal Range	Investigator
.....	50 mg.	Bilirubin retention less than 30% in 3 hours	Gargill (1931)
.....	1-1.5 mg./kg. of body wgt.	Less than 6% retention in 3 hours	Soffer (1935)
Pregnant women . . . .	1-1.5 mg./kg. of body wgt.	Less than 6% retention in 3 hours	

## PROTEIN AND AMINO ACID TOLERANCE TESTS

After administration of casein hydrolysate and gelatin, the blood amino nitrogen concentration and the plasma amino acid concentration rise in normal men (see Table 90).<sup>32, 58</sup>

## POTASSIUM TOLERANCE TEST

In normal persons there is no effect on the arterial plasma potassium concentration after an oral potassium dose of 10 to 20 mg. per pound of body wt.<sup>60</sup>

## WATER EXCRETION TEST

The water excretion test of Robinson and his co-workers<sup>19</sup> was designed and used in the diagnosis of adrenal cortical insufficiency. An *A* value over 30 is

regarded as normal; values less than 25 are regarded as abnormal. The A value is obtained by solving the following equation:

$$\frac{\text{Urea in urine mg. 100 ml.}}{\text{Urea in plasma mg. 100 ml.}} \times \frac{\text{Chloride in plasma mg. 100 ml.}}{\text{Chloride in urine mg. 100 ml.}} \times \frac{\text{Volume of day urine ml.}}{\text{Volume of night urine ml.}}$$

These values were confirmed by Schneider,<sup>48</sup> who tested thirty-four patients with normal adrenal function.

TABLE 90  
PROTEIN AND AMINO ACID TOLERANCE  
Amino Nitrogen Concentration in Whole Blood Mg./100 Ml. above Fasting Level\*

Subjects	Dose in Grams		Time in Minutes						Investigator
			30	60	120	180	240	300	
9 Infants	Casein hydrolysate 1.3 hrs/kg. of body weight	Mean Range	2.0 0.1-4.0	2.6 1.2-4.1	2.8 0.7-4.5	1.9 0.1-3.8	1.0 -0.5 to +4.1	0.3 -1.5 to +1.8	West, Wasserman, Eysenck (1946)
8 Infants	Gelatin, 15 gm./kg. of body weight	Mean Range	1.6 0.6-3.8	2.3 1.7-3.4	2.6 2.0-3.5	2.2 0.9-3.2	1.4 0.0-2.0	0.6 -0.5 to +1.7	

Plasma Amino Acid Concentration in Whole Blood—Mg./100 Ml.

Subjects	Dose in Grams		Time in Minutes						Investigator
			0	5	15	30	60	90	
9 Children	Casein hydrolysate I.V., 40 ml. of 10% solution	Mean Range	3.4 2.6-4.2	5.9 4.6-7.3	5.2 4.1-6.2	4.1 3.2-4.9	3.7 3.0-4.4	3.4 3.0-8.0	Lytle et al. 1943

\* Capillary blood.

## SODIUM CHLORIDE EXCRETION TEST

In normal persons the urinary output of sodium and chloride after desoxycorticosterone and sodium chloride administration is reduced from the output values obtained after a base line sodium chloride injection. In Cushing's disease the desoxycorticosterone increases the percentage of sodium and chloride excreted in the urine after sodium chloride injection.<sup>53</sup>

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## Chapter 19

### ANIONS AND CATIONS IN BLOOD AND SERUM

#### TOTAL BASE IN SERUM

TOTAL BASE denotes the summation of the inorganic cation concentration of serum (exclusive of  $\text{NH}_4$ ), i. e., sodium, potassium, calcium and magnesium concentration in serum. Normal values for total base are given in Table 91; values for individual cations, in Tables 92, 93, 94, 96, 105 and 117.

TABLE 91  
TOTAL BASE IN SERUM

<i>Number of Subjects</i>	<i>Range mEq./L.</i>	<i>Average</i>	<i>Method</i>	<i>Investigator</i>
10.....	142.0-149.3	146.3	Stadie and Ross (1925)	Sunderman (1931)
10.....	144.6-148.8	...	Summation of cations	
20.....	144.0-149.0	146.5	Conductivity	Sunderman (1942)
10.....	142.0-153.1	146.5	Hald (1933)	Hald (1933)
10.....	141.6-154.0	145.8	Summation of cations	
5.....	153.8-158.3	156.5	Electrodialysis	Keys (1936)
37.....	147.7-156.8	153.1	Electrodialysis	Consolazio and
37.....	147.6-156.0	152.5	Summation of cations	Talbott (1940)

#### SODIUM AND POTASSIUM

Sodium and potassium of whole blood appear to be present entirely in the ionic state. In cells, the predominant cation is potassium; in the plasma and extracellular fluid, it is sodium.

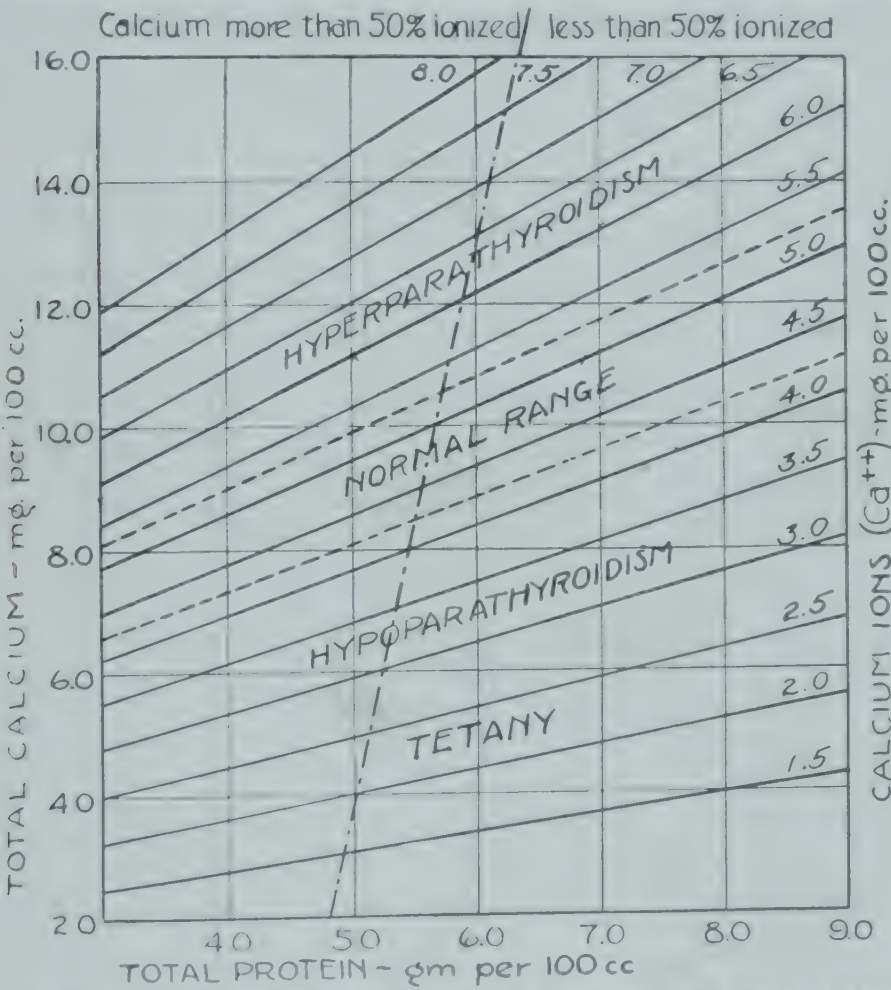
TABLE 92  
NORMAL RANGES OF SODIUM AND POTASSIUM IN SERUM

<i>Number of Normal Serum Determinations</i>	<i>Sodium</i>		<i>Potassium</i>		<i>Method</i>	<i>Investigator</i>
	<i>mEq./liter</i>	<i>Mg./100 Ml.</i>	<i>mEq./Liter</i>	<i>Mg./100 Ml.</i>		
10.....	.....	.....	4.8-5.1	18.8-19.9	Unashed serum	Kramer and Tisdall (1921)
16.....	.....	.....	4.6-5.4	18.0-21.1	Ashed serum	
4.....	.....	.....	3.6-4.6	14.1-18.0	Ash	Meyers and Short (1921)
6.....	.....	.....	3.1-5.2	12.1-20.3	Precipitation	Atchley et al. (1923)
14.....	143.9-150.8	331-347	.....	.....	Iodometric	Rourke (1928)
17.....	140.4-152.1	323-350	.....	.....	Direct gravimetric	Kramer and Tisdall (1921)
.....	145.0-150.0	344-345	.....	.....	Ashed	
37.....	135.0-143.0	311-329	3.9-5.6	15.2-21.9	Electrodialysis	Consolazio and Talbott (1940)
11.....	.....	.....	4.0-7.1	15.6-27.8	Titration	Consolazio and Talbott (1938)
10.....	133.6-137.3	307-316	.....	.....	Gravimetric	Sunderman (1930)
10.....	.....	.....	3.8-4.3	14.9-16.8	Titrimetric	
8.....	134.2-141.0	309-324	3.1-5.3	12.5-20.7	Dry ash	Hald (1946)
3.....	139.0-142.1	320-327	4.3-5.0	16.8-19.6		Lea and Guest (1929)
6.....	.....	.....	3.7-5.6	14.5-21.9	Colorimetric	Albanese and Wagner (1944)
107.....	135.5-153.2	312-352	3.6-6.2	14.1-24.2	Flame photometer	Marinis et al. (1947)

TABLE 93

CONCENTRATIONS OF SODIUM AND POTASSIUM IN BLOOD, SERUM AND CELLS  
(Hald, 1946)<sup>25</sup>

Number of Subjects 8	Sodium			Potassium		
	Blood mEq./L.	Serum mEq./L.	Cells mEq./L.	Blood mEq./L.	Serum mEq./L.	Cells mEq./L.
age.....	85.4	137.1	21.2	44.8	4.4	95.1
um.....	91.0	141.0	25.3	48.8	5.3	100.0
um.....	79.3	134.2	15.7	40.3	3.1	91.8



47. Chart for calculation of [Ca<sup>++</sup>] from total protein and total calcium of serum or plasma. McLean, F. C., and Hastings, H. B.: *Am. J. M. Sc.*, vol. 189.

CALCIUM IN SERUM

In circulating blood the cells are practically devoid of calcium. Values for total calcium in serum are given in Table 94. Calcium in serum is divided between calcium ions and calcium bound to protein. The calcium ion concentration of serum is normally maintained within a narrow range of 4.25 to 5.25 mg. per 100 ml. (Figure 47).

Table 95 gives normal values for calcium bound to protein as well as calcium bound to albumin and to globulin. These values are expressed as milligrams per 100 gm. of water.

TABLE 94  
TOTAL CALCIUM IN SERUM

Number of Subjects	Range		Average		Method	Investigator
	mEq./L.	mg./100 Ml.	mEq./L.	mg./100 Ml.		
10.....	5.0-5.5	10-11	5.0	10	Clark and Collip (1925)	Sunderman (1931)
10.....	5.1-5.8	8.2-11.6	5.0	10		Hald (1933)
37.....	4.53-5.35	9.1-10.7	5.0	10	Clark and Collip (1925)	Consolazio and Talbott (1947)

TABLE 95  
NORMAL SERUM CALCIUM AND THE CALCIUM-BINDING POWER OF THE SERUM PROTEINS  
(Modified from Rawson and Sunderman, 1948)<sup>49</sup>

Normal Subject	Total Calcium Serum Mg. 100 ml.)	Diffusible Calcium Filtrate Mg. 100 ml.)	Calcium Partition					Calcium-Binding Power	
			Total Mg. per 100 Gm. H <sub>2</sub> O)	Diffusible (Mg. per 100 Gm. H <sub>2</sub> O)	Bound (Mg. per 100 Gm. H <sub>2</sub> O)	Bound to Albumin (Mg. per 100 Gm. H <sub>2</sub> O)	Bound to Globulin (Mg. per 100 Gm. H <sub>2</sub> O)	Albumin (Mg. per Gram)	Globulin (Mg. per Gram)
AR.....	10.36	4.16	11.03	4.18	6.85	4.34	2.51	1.02	0.83
DL.....	10.42	4.76	11.11	4.78	6.33	3.84	2.49	0.85	0.96
FS.....	10.00	4.84	10.65	4.86	5.79	3.75	2.04	0.83	0.75
JM.....	10.20	4.99	10.87	5.01	5.86	3.34	2.52	0.77	0.78
AP.....	10.00	4.99	10.62	5.01	5.61	2.71	2.90	0.77	0.83
Average								0.85 (S.E. = 0.45)	0.83 (S.E. = 0.45)

MAGNESIUM

Magnesium is distributed between serum and cells with an excess in the corpuscles. To convert values of magnesium from milliequivalents per liter (Table 96) to milligrams per 100 ml., multiply by the factor 1.22.

TABLE 96  
MAGNESIUM IN BLOOD

Number of Subjects	Range (mEq./L.)	Average	Investigator
.....	Serum 1.8-2.2	1.96	Sunderman (1931)
10.....	Serum 1.4-2.4	1.7	Hald (1933)
37.....	Serum 2.2-3.2	2.67	Consolazio and Talbott (1947)
.....	Serum 1.7-1.8	1.8	Kunkel et al. (1947)
.....	Whole blood 3.0-3.7		

TABLE 97  
pH OF NORMAL BLOOD PLASMA OR SERUM\* AT 38°C.

Subjects	Type of Sample	Maximum Value	Minimum Value	Mean	Standard Deviation	Method	Investigator
27 Men	Venous	7.41	7.28	7.361	0.034	Colorimetric	Cullen and Robinson 1923
39 Men	Venous	7.45	7.35	7.399	0.064	Colorimetric	Shock and Hastings 1934
17 Women	Venous	7.45	7.38	7.415	0.025	Colorimetric	
50 Men	Arterial	7.455	7.374	7.424	0.016	Electrometric	Gibbs et al. 1942
50 Men	Venous (intrajugular)	7.397	7.321	7.371	0.015	glass electrode	

\* The pH of whole blood has been shown to be the pH of the plasma (Parsons, 1917).

## HYDROGEN ION CONCENTRATION OF BLOOD

The range of pH in the blood plasma of normal persons is from 7.36 to 7.41 at 38° C.

The average change in acidity of the blood (pH) in a normal resting person as it flows through the body as a whole has been taken as 0.03.<sup>7</sup> Gibbs and his co-workers<sup>20</sup> report an average of 0.053 units lower in blood obtained from the jugular vein as compared with arterial blood.

D'Elseaux and his colleagues<sup>17</sup> determined the pH of the arterial blood of eighteen normal young men under basal conditions and procaine anesthesia by the gasometric procedure. The average value obtained was 7.397, to which they added 0.02 to obtain 7.42 to correct for the effect of glycolysis and oxygen unsaturation. It appears that under basal conditions the fluctuation in arterial pH of a normal person is limited to changes in the third digit after the decimal point.

## CARBON DIOXIDE IN BLOOD AND PLASMA

Total carbon dioxide in blood represents that present as bicarbonate plus that contained in carbonic acid. Since pH defines the ratio of the concentrations of  $\text{H.HCO}_3$  and  $\text{B.HCO}_3$  in blood plasma, individual values for each of

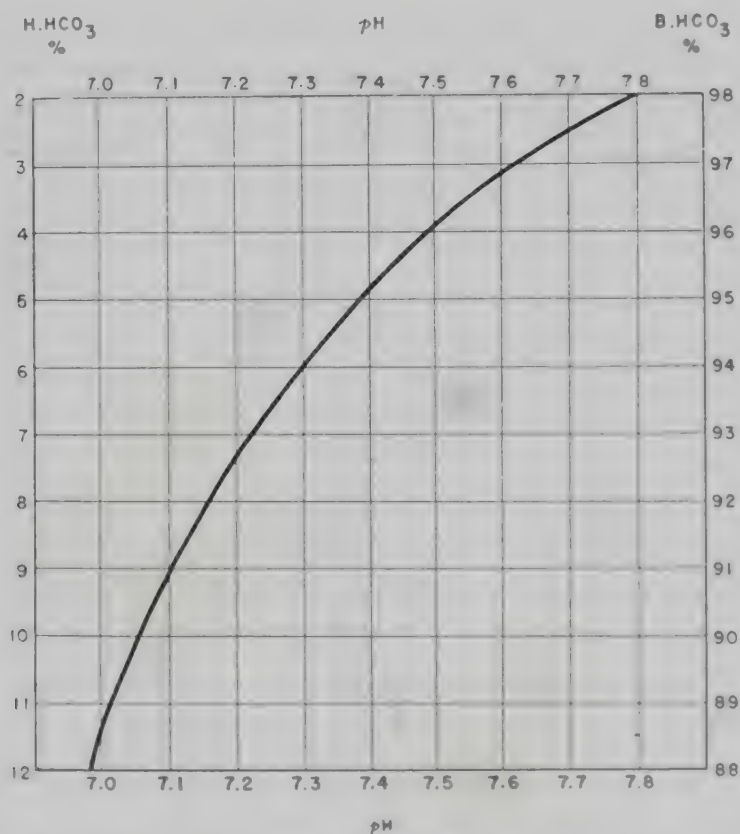


Fig. 48. Partition of total plasma— $\text{HCO}_3$  ("total  $\text{CO}_2$ ")—in relation to pH. Total  $\text{CO}_2 = \text{B.HCO}_3 + \text{H.HCO}_3$ .

Example: Serum total  $\text{CO}_2 = 25 \text{ mM/L}$

Serum pH = 7.39

$\text{H.HCO}_3 = 5\% \times 25 = 1.25 \text{ mM/L}$

$\text{B.HCO}_3 = 95 \times 25 = 23.75 \text{ mM/L}$

TABLE 98

CARBON DIOXIDE CONTENT AND CARBON DIOXIDE TENSION OF BLOOD, BLOOD SERUM, AND PLASMA IN A NORMAL RESTING PERSON

Subjects	Sample	Total Carbon Dioxide Content Volumes per Cent Values in Millimols per Liter*				Carbon Dioxide Tension (pCO <sub>2</sub> ) Millimeters of Mercury				Investigator
		Maximum	Minimum	Average	Std. Dev.	Maximum	Minimum	Average	Std. Dev.	
50 Men	Blood (arterial)	50.4 (22.7)	44.6 (20.1)	48.2 (21.7)	1.4	44.9	36.2	39.9	1.8	Gibbs, Lennox, Nims and Gibbs (1942)
	Blood (venous)	57.7 (25.9)	51.0 (22.9)	54.8 (24.6)	1.6	54.3	46.9	49.9	1.9	
39 Men	jugular Blood	54.3	42.7	49.6	2.68	53.9	36.0	43.9	3.7	Shock and Hastings 1934
	(finger)	(24.4)	(19.2)	(22.3)						
17 Women	Blood	55.6	41.8	48.7	3.02	44.4	36.9	40.1	2.7	Cullen and Robinson 1923
	(finger)	(25.0)	(18.8)	(21.9)						
23 Men	Blood	61.2	52.0	57.4	2.8	.....	.....	.....	.....	Peters, Bulger, Eisenman and Lee 1926)
	(venous)	(27.5)	(23.4)	(25.8)						
14 Men	Plasma	71.5	59.6	67.6		.....	.....	.....	.....	Shock and Hastings 1934
	(venous blood)	(32.1)	(26.8)	(30.4)						
17 Men	Serum	73.1	53.5	63.7		.....	.....	.....	.....	Shock and Hastings 1934
10 Women	(venous blood)	(32.9)	(24.1)	(28.6)						
39 Men	Serum	66.6	51.8	61.2		.....	.....	.....	.....	Shock and Hastings 1934
	(finger blood)	(29.9)	(22.8)	(27.5)						
17 Women	Serum	66.2	49.6	58.4		.....	.....	.....	.....	Shock and Hastings 1934
	(finger blood)	(29.8)	(22.3)	(26.3)						

\* Millimols per liter =  $\frac{\text{Volumes per cent}}{2.224}$ .

these can be derived from a determination of  $pH$  together with the over-all measurement of their common ion,  $-HCO_3$ , which is provided by measurements of "total carbon dioxide," or "carbon dioxide content" (see Fig. 48).

TABLE 99

NORMAL VALUES OF BLOOD AND SERUM CARBON DIOXIDE CAPACITY  
(Peters and Van Slyke, 1931)<sup>46</sup>

<i>Specimen</i>	<i>Volumes per Cent</i>			<i>Investigator</i>
	Maximum	Minimum	Average	
Arterial blood at 40 mm. of $CO_2$ tension and $38^\circ C$ .....	50.2	42.7	47.1	Barr, Himwich and Green (1923)
Venous blood at 40 mm. of $CO_2$ tension and $38^\circ C$ .....	55.9	43.3	49.3	Peters, Barr and Rahn (1921)
Venous serum at 40 mm. of $CO_2$ tension and $38^\circ C$ .....	59.9	49.5	55.0	Peters, Bulger, Eisenman and Lee (1926)

TABLE 100

BICARBONATE AND FREE CARBON DIOXIDE (CARBONIC ACID) IN NORMAL BLOOD PLASMA

Subjects	Type Sample	$pH = pK' + \text{Log } \frac{BHCO_3}{H_2CO_3}; CO_2 \text{ as } BHCO_3$ Volumes per Cent Millimols per Liter*				$pK' = 6.1; CO_2 \text{ as } H_2CO_3$ Volumes per Cent Millimols per Liter*				Investigator
		Maximum	Minimum	Average	Std. Dev.	Maximum	Minimum	Average	Std. Dev.	
39 Men	Serum (finger blood) <sup>44</sup>	63.4 (28.5)	49.4 (22.2)	58.3 (26.2)	3.23	3.44 (1.54)	2.42 (1.09)	2.94 (1.32)	0.248	Shock and Hastings 1934
17 Women	Serum (finger blood) <sup>44</sup>	63.4 (28.5)	47.1 (21.2)	55.4 (24.9)	3.74	2.98 (1.34)	2.48 (1.11)	2.69 (1.21)	0.152	
14 Men	Plasma venous	67.2 (30.2)	58.7 (26.4)	63.6 (28.6)	.....	4.22 (1.9)	2.89 (1.3)	3.56 (1.6)		

\* Millimols per liter =  $\frac{\text{Volume per cent}}{2.224}$ .

Gram 1924 calculated from data of Cullen and Robinson

TABLE 101  
SEX DIFFERENCES IN ACID-BASE BALANCE OF BLOOD  
(From Shock and Hastings, 1934)<sup>58</sup>

Subjects	V <sub>c</sub>		pH of Serum at 38°C. pH <sub>s</sub>		CO <sub>2</sub> Content of Whole Cutaneous blood (CO <sub>2</sub> ) <sub>b</sub>		CO <sub>2</sub> Tension pCO <sub>2</sub> (mm. Hg)		CO <sub>2</sub> Content as BHCO <sub>3</sub> in Serum from Whole Cutaneous Blood (BHCO <sub>3</sub> ) <sub>s</sub>	
	Arithmetical Mean	S.D.	Arithmetical Mean	S.D.	Arithmetical Mean	S.D.	Arithmetical Mean	S.D.	Arithmetical Mean	S.D.
39 Men	0.475 ± 0.003	0.029	7.399 ± 0.007	0.064	22.30 ± 0.13	1.204	43.88 ± 0.40	3.70	26.20 ± 0.16	1.45
17 Women	0.410 ± 0.005	0.029	7.415 ± 0.004	0.025	21.899 ± 0.233	1.359	40.06 ± 0.37	2.26	24.88 ± 0.27	1.68
57 Men and women	0.455 ± 0.004	0.041	7.402 ± 0.008	0.087	22.19 ± 0.11	1.245	42.86 ± 0.35	3.96	25.79 ± 0.11	1.26
131 Single observations	0.465 ± 0.002	0.038	7.399 ± 0.004	0.070	22.34 ± 0.08	1.391	43.68 ± 0.27	4.67	26.10 ± 0.10	1.69

CO<sub>2</sub> and BHCO<sub>3</sub> are given in millimols per liter of blood; pCO<sub>2</sub> in millimeters of mercury.

S.D. = standard deviation of the distribution.

\* Each figure used for an individual is the mean of all observations made on that individual.

## CHLORIDES

Values of chloride in whole blood are more variable than those of serum corpuscles, owing to the variable proportion of cells to plasma. The chloride concentration of whole blood does not indicate accurately the chloride concentration in either cells or plasma. Gram<sup>21</sup> found that in defibrinated normal human blood the ratio of  $Cl_c$  to  $Cl_s$  is from 0.52 to 0.58, where  $Cl_c$  and  $Cl_s$  represent the chloride concentrations of cells and serum, respectively.

TABLE 102  
CONCENTRATION OF CHLORIDE IN BLOOD\*

Portion of Blood	Serum or Plasma	Whole Blood	Corpuscles	Investigator
Arterial	$\left\{ \begin{array}{l} 100.6-107.6 \text{ mEq./L.} \\ 357-381 \text{ mg./Cl/100 ml.} \\ 588-630 \text{ mg./NaCl/100 ml.} \end{array} \right.$			Gram (1924)
...	.....	.....	$\left\{ \begin{array}{l} 52.5 \text{ mEq./L.} \\ 186 \text{ mg. Cl/100 ml.} \\ 306 \text{ mg./NaCl/100 ml.} \end{array} \right.$	Gram (1924)
...	.....	$\left\{ \begin{array}{l} 77.0-90.6 \text{ mEq./L.} \\ 273-321 \text{ mg. Cl/100 ml.} \\ 450-529 \text{ mg. NaCl/100 ml.} \end{array} \right.$		Gram (1924)
...	$\left\{ \begin{array}{l} 98.5-104.5 \text{ (av. 102.1) mEq./L.} \\ 349-371 \text{ mg./Cl/100 ml.} \\ 575-611 \text{ mg. NaCl/100 ml.} \end{array} \right.$			Sunderman (1931)

See also Table 105.

## PHOSPHORUS

Table 103 gives the distribution of the various forms of phosphorus between blood and serum or plasma. According to Gibbs and his co-workers<sup>20</sup> it appears to be no significant difference in the distribution between arterial and venous blood. The serum of infants and children is from 1 to 3 mg. higher in concentration than that of adults.

The total phosphorus of whole blood or serum is composed of phospholipids, inorganic phosphate and organic phosphate esters. The ester phosphorus (acid-soluble phosphorus) is found chiefly in the erythrocytes, the principal ester of the erythrocytes being diphosphoglyceric acid, which is high in childhood.

The total phosphorus of whole blood and serum is determined after the organic matter has been destroyed by acid digestion. The lipid phosphorus is determined on the alcohol and ether extract of blood or serum. The total acid-soluble phosphorus represents the fraction obtained by acid digestion of the trichloroacetic acid filtrate of blood or serum. The inorganic phosphorus represents the fraction obtained on trichloroacetic acid filtrates without acid digestion. The ester phosphorus represents the difference between the total acid-soluble phosphorus and the inorganic phosphorus.

The total phosphorus of blood or serum determined directly is within the experimental error equal to the sum of the lipid, inorganic and ester phosphorus.

Gibbs and his associates<sup>20</sup> determined the inorganic phosphorus in the serum from arterial blood and internal jugular venous blood of fifty normal

adults. There were no significant differences in values. The range of the value was 2.7 to 4.5 mg. per 100 ml.; the average value was 3.4 mg. per 100 ml., and the standard deviation was 0.4. These values are in good agreement with those in Table 103.

TABLE 103  
DISTRIBUTION OF PHOSPHORUS IN THE BLOOD OF NORMAL PERSONS IN MILLIGRAMS PER 100 ML. OF BLOOD CELLS OF SERUM  
(Peters and Van Slyke, 1931)<sup>46</sup>

	Total Phosphorus		Lipoid Phosphorus		Acid-Soluble Phosphorus		Inorganic Phosphorus	
	Cells	Serum	Cells	Serum	Cells	Serum	Cells	Serum
Adults.....	47-114	8-18	11-27	5-13	44-82	2.5-5.5	?	2.4
Infants.....	49- 90	5-14	14-24	3- 7	43-70	4-8	?	4.7

SULFUR

Inorganic sulfur appears to be fairly evenly distributed between the cells and serum. Ethereal sulfur represents an increment obtained after acid hydrolysis of the protein-free filtrate. The unequal distribution of neutral sulfur, according to Peters and Van Slyke,<sup>46</sup> must be partially due to the presence of ergothionine and glutathione.

TABLE 104  
CONCENTRATION OF SULFUR IN BLOOD

	Whole Blood	Serum or Plasma	Investigator
Inorganic sulfate as Sulfur:			
Mg./100 ml.....	0.1-1.1	0.5-1.1	Denis (1921)
MEq./L.....	...	0.3-0.7	
MEq./L.....	...	0.4-1.0	Loeb and Benedict (1927)
Mg./100 ml.....	...	(average, 0.7)	
		0.87-1.47	Power and Wakefield
		(average, 1.11)	(1938)
		(S.D. $\pm$ 0.13)	
Ethereal sulfate as sulfur:			
Mg./100 ml.....	0.1-1.0	0.1-1.0	Denis (1921)
Neutral sulfur:			
Mg./100 ml.....	2.2-4.5	1.7-3.5	Denis (1921)
Glutathione (reduced):*			
Mg./100 ml.....	25-41	...	Woodward and Fry (1922)
	(average, 34)		
Ergothionine (thionine):			
Mg./100 ml.....	4.2-15	...	Behre and Benedict (1928)
	(average, 7.5)		

\* After zinc reduction the value increased 3 to 11 gm. per 100 ml., which was assumed to be oxidized glutathione.

TABLE 105

DISTRIBUTION OF ANIONS AND CATIONS IN SERUM AND BLOOD CELLS (IN MILLIEQUIVALENTS PER LITER)

	Na	K	Ca	Mg	Inorganic P	Cl	HCO <sub>3</sub>	Base Albuminate	Base Globuli- nate	Investigator
Serum	129.1-143.3	3.0-7.6	4.1-5.8	1.2-2.4	1.9-2.8	100.0-105.4	24.6-29.8	8.6-13.8	2.6-5.4	Hald
Cells	10.0-27.1	71.8-101.7	0-1.4	3.5-6.2						
Serum	129.4-154.0	2.9-7.6	4.0-5.5	0.8-2.5	1.9-4.9	99.0-108.0				Composite
Cells	-17.0*-27.1	80.0-120.0	0.6-1.4	1.9-5.5	...	51.0-56.0				Snyder and Kat-
Serum	128.4-143.3	4.0-6.1	4.0-5.6	1.9-2.3	1.7-2.9	100.0-107.4				zenelbogen
Cells	3.9-15.9	80.8-93.8	0-0	3.1-4.5	Trace- 1.9	53.7-63.5				

\* Negative results are possible, since the determinations were not made on cells directly, but were calculated from whole blood, plasma and hematocrit values.

TABLE 106

SYNOPSIS OF DIFFERENCES BETWEEN ARTERIAL AND VENOUS BLOOD

	Arterial	Venous
pH (serum).....	7.30-7.41	7.27-7.37
Total CO <sub>2</sub> (blood, *.....	32.5-60.0 volumes per cent	37.7-65 volumes per cent
Free CO <sub>2</sub> .....	1.5-4.0 volumes per cent	1.7-4.2 volumes per cent
BHCO <sub>3</sub> .....	31-56 volumes per cent	36-61 volumes per cent
Chlorides (serum).....	101.5-107.5 mEq./L.	98.5-104.5 mEq./L.
Percentile oxygen saturation of		
hemoglobin.....	93-98 per cent	62-85 per cent
Oxygen content.....	12-22 volumes per cent	11-16 volumes per cent
Glucose.....	80-110 mg./100 ml.	70-100 mg./100 ml.

$$* \text{ Millimols CO}_2 \text{ per L.} = \frac{\text{Volumes per cent CO}_2}{2.24}$$

## IRON

IRON IN WHOLE BLOOD. The concentrations of iron in whole blood of normal persons are given in Table 106a. Over 99 per cent of the iron in whole blood is contained in the erythrocytes. (See Chapter 16, page 123, for iron concentration of human hemoglobin.)

TABLE 106a

TOTAL BLOOD IRON OF NORMAL SUBJECTS  
Mg./100 Ml. of Whole Blood

Number of Subjects	Mean Value	Range of Values	Investigator
200 males.....	50.1		Sachs et al. (1933)
10 males.....	50.8	44-56	Sachs et al. (1943)
100 females.....	43.4		Sachs et al. (1933)
10 females.....	45.1	42-48	Sachs et al. (1943)
25 pregnant women.....	40.4		Sachs et al. (1935)
Fetus.....	54.3		Sachs et al. (1935)
71 children, 1½ months to 15 years.....	40.6		Sachs et al. (1935)

IRON IN SERUM (PLASMA). The serum (plasma) iron concentration depends upon a number of factors, such as the rate of absorption of iron from the intestinal tract, the amount available from hemoglobin destruction, and from the equilibrium resulting from iron passing to and from the tissues. A specific globulin, Fraction IV<sub>7</sub> of Cohn, has been reported to bind iron in the plasma. Table 106b is a summary of the concentrations of serum iron reported in the literature (Cartright, 1947).

There is no apparent difference between the concentrations of iron in serum and plasma (Moore et al., 1937). The average plasma iron concentration for men is higher than for women and is higher in younger age groups than in the elderly (Eckstrom, 1944).

TABLE 106b

SERUM IRON OF NORMAL PERSONS  
Micrograms/100 Ml. of Serum

Men			Women			Investigator
Number of Subjects	Mean Value	Standard Deviation	Number of Subjects	Mean Value	Standard Deviation	
126.2	21.4	25	88.5	18.8	Heilmeyer and Plotner (1936) Moore et al. (1937) Vahlquist (1940) Powell (1944) Cartwright et al. (1948)	
121.5	25.8	15	97.6	23.7		
142.0	43.0	50	123.0	31.6		
143.0	24.0	35	117.0	26.5		
105.1	30.3	43	104.3	36.4		

## COPPER

Copper appears to be fairly equally distributed between cells and plasma. Significant difference exists between the sexes.

TABLE 107

## RANGE OF SERUM COPPER VALUES

Method	Serum Copper (Gamma) per Cent
Trichloroacetic acid <sup>35</sup> .....	72- 95
Trichloroacetic acid <sup>64</sup> .....	183-245
Dry ashing <sup>23</sup> .....	56- 75
Catalytic <sup>67</sup> .....	82
Dry ashing <sup>53</sup> .....	82-132
Trichloroacetic acid <sup>11</sup> .....	92-135 (average, 116)
	103-159 (average, 131)
Trichloroacetic acid <sup>13</sup> .....	86-161 (average, 118.6±1.2)

## LEAD

Lead may be present in the blood of normal subjects, ranging from 0.005 to 0.13 mg. per 100 ml.<sup>13</sup> This upper limit (0.13 mg. per 100 cc.) is probably too high and any value above 0.008 mg. per 100 ml. should be regarded as abnormal (table 207a).

## TRACE METALS

In addition to lead and copper, Kehoe and his associates report the mean concentrations of the following trace metals present in normal whole blood (mg. per 100 gm.): manganese, 0.015; aluminum, 0.013; tin, 0.012; and silver, 0.004.<sup>13</sup> They found practically all the manganese, lead and tin to be contained in the red elements of the blood, while aluminum was almost entirely in the plasma.

## BLOOD IODINE

There is a wide variation in the range of normal values for blood iodine depending upon the methods used. Some investigators<sup>4</sup> have maintained that the values for blood iodine in men are greater than those in women. Later workers,<sup>8, 50</sup> however, have not confirmed this.

TABLE 108  
NORMAL BLOOD TOTAL IODINE VALUES  
(Riggs and Man, 1940)<sup>50</sup>

Method	Investigator	Year	Subjects with Normal Thyroids			
			Number of Cases	Maximum	Minimum	Average
Alkaline ashing.....	Veil and Sturm	1925	36	20.0	10.0	12.8
	Orr and Leitch	1929	16	10.0	4.0	6.0
	Fowweather	1930	13	5.2	3.6	4.3
	Davis, Curtis and Cole	1934	28	16.2	8.5	11.9
	Perkin and Cattell	1936	114	12.0	1.5	6.8
	McCullagh and McCullagh	1936	...	12.0	8.0	10.0
	Grauer and Saier	1939	9	3.9	2.3	3.0
Closed combustion methods	Baumann and Metzger	1932	..	10.0	8.6	9.6
	McClendon and Bratton	1938	..	14.0	2.0	..
Chromic acid ashing.....	Leipert	1934	40	17.0	9.0	13.0
	Stevens	1937	15	6.9	3.3	4.8
	Baumann and Metzger	1937	20	4.4	2.3	3.0
	Fashena	1938	79*	12.0	3.0	6.6
	Matthews, Curtis and Brode	1938	..	..	..	4.0
Permanganate ashing.....	Grauer and Saier	1939	9	4.5	2.2	3.2
	Riggs and Man	1940	20	3.7	2.5	3.1

\* Children from birth to 13 years old.

TABLE 108a  
Protein-Bound Serum Iodine

Number of Subjects	Average $\gamma/100$ Ml.	Range $\gamma/100$ Ml.	Method	Investigator
39 Children (3-13 years).....	5.5	4.0-7.0	Riggs, modified	Talbot, Butler, Saltzman and Rodriguez (1944)
11 Young Adults	7.0	6.0-8.4	Riggs, modified	Talbot, Butler, Saltzman and Rodriguez 1944

The total iodine concentration of serum in normal persons is usually regarded to vary between 5 and 12 micrograms per 100 ml. Iodine in serum is

in both organic and inorganic fractions, the former being represented by tri- and di-iodotyrosine (T and D fractions) (Table 108a). It is generally estimated that about 85 per cent of the total iodine in the serum is bound to protein. In whole blood about half or less of the iodine is alcohol-insoluble, and 50 per cent or less is probably in the inorganic state.<sup>27</sup> Silver,<sup>28</sup> however, concluded that all the iodine normally circulating in the blood can be extracted with either hot or cold alcohol, provided that enough of the solvent is used and extraction is continued for a sufficient period of time. Silver also observed that all the iodine is in the plasma and that practically all of it is in a form that is dialyzable.

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## Chapter 20

### BODY FLUIDS

#### BLOOD AND PLASMA VOLUME

methods have been devised for measuring blood and plasma volume in. These include dilution of the blood after intravenous infusions; replacement methods; the introduction of slowly diffusible, nontoxic substances, such as acacia, foreign serum, hemoglobin, radioactive iron, radioactive phosphorus, carbon monoxide, and vital dyes (neutral vital red, brilliant vital red,

TABLE 109

NORMAL VALUES FOR PLASMA AND WHOLE BLOOD

<i>Subject</i>	<i>Method</i>	<i>Plasma or Serum</i> ( <i>Ml./Kg. Body Wt.</i> )	<i>Blood Volume</i> ( <i>Ml./Kg. Body Wt.</i> )	<i>Investigator</i>
terminations on males.....	Dye	42 -46	78 -97	Keith, Rowntree and Geraghty (1915)
terminations on males.....	Dye	36.3-44.3	60.5-78.6	Gibson and Evans (1937)
es.....	Dye	35.2-58.2	66.2-97.7	Gibson and Evans (1937)
males.....	Dye	33.4-52.3	46.3-85.4	
ects:				
female.....	Dye	45.5 (av.)	80.5 ± 8.6	Hopper, Tabor and Winkler (1944)
ale.....	CO	45.3 (av.)	80.2 ± 5.5	Crooke and Morris (1942)
ales.....	Dye	49.8 (av.)	.....	Sunderman and Austin (1936)
emales.....	Dye	47.7 (av.)	.....	Plesch (1922)
ales.....	Dye	40 -46	.....	Salvesen (1919)
ales.....	CO	.....	47 -61	Chang and Harrop (1928)
ales.....	CO	.....	52 -70	Lucas and Dearing (1921)
emales.....	CO	.....	63 -76	
ales.....	CO	.....	.....	
ants 2½ hrs. to days old.....	Dye	.....	147	
ants 15 days to .....	Dye	.....	109	
ants 1 hr. to 10 s old.....	Dye	.....	98.3	Robinow and Hamilton (1941)
ject.....	Dye	44.8	77.2	Moore (1946) Nylin (1945)

to red, trypan blue, trypan red, Evan's blue, T-1824, and others). Of these, dye methods have proved to be most suitable for routine clinical use. Efforts to eliminate sources of error owing to dye lost during the mixing period have led to numerous modifications of the original method described by Keith, Rowntree and Geraghty.\* Owing to differences in techniques, the measurements

of blood volume by various investigators are not always in agreement. Some values for blood and plasma volumes of normal persons are given in Table 109.

The whole blood is about 9 per cent and the plasma about 5 per cent of the total body weight. Expressed in terms of body surface, the blood volume amounts to about 3.3 liters per square meter of body surface. Expressed in relation to body weight, the whole blood is about 85 ml. per kilogram of body weight, and the plasma is approximately 45 ml. The blood volume of an average man 70 kilograms of weight is approximately 6000 ml.

Estimations of blood volume by the injection of erythrocytes labelled with radioactive iron or phosphorus yield somewhat lower values than the dye methods.<sup>12</sup> With these procedures the amount of circulating blood corpuscles in normal persons is approximately 33.4 gm. per kilogram of body weight.

## BODY FLUIDS, EXTRACELLULAR FLUIDS AND WATER BALANCE

The body fluids are composed of water and solutes. Any consideration of their behavior under pathologic conditions presupposes a knowledge of their normal behavior. Water constitutes about 70 per cent of the normal body weight, and it is convenient to partition it into two major fractions: (1) *intracellular water*, which constitutes 45 to 50 per cent of the body weight and forms an essential component of protoplasm, and (2) *extracellular water*, which amounts to about 25 per cent of the body weight. The extracellular water may be subdivided into two parts: (1) the *vascular fluids*, representing about 5 per cent, and (2) the *interstitial fluids*, comprising about 20 per cent of the body weight. The vascular fluids and interstitial fluids together constitute the extracellular water.

Methods for measuring these various body fluids are available, but, for the most part, are somewhat complicated and time-consuming, and may be adapted only to selected cases. For clinical purposes, as previously indicated, the serum volume may be measured by either of two methods: (1) by the injection of a known amount of a vital dye into the circulation and measuring its concentration after thorough mixing has occurred, or (2) by the inhalation of a measured amount of carbon monoxide and determining the concentration of carbon monoxide hemoglobin in the whole blood. The volume of whole blood may then be calculated and the percentage of serum may be estimated from the hematocrit readings.

The *extracellular fluids* (i. e., the sum of the vascular and interstitial fluids) are measured by methods that use the introduction of substances to which most cells appear to be impermeable and which are not oxidized or otherwise altered in the body. Such substances include sucrose, thiocyanates, sulfates and bromides. Values for extracellular fluids are given in Table 110.

Attempts have been made to determine the *total amount of body fluids* directly, so that the fluids in the intracellular fraction might be calculated. Certain chemicals, such as thiourea, appear to penetrate into cells and to be dissolved in all the body water. It is only fair, however, to state that such direct methods have not proved to be satisfactory and are still in the experimental stage.

Although the direct measurement of the body fluids is uncertain, nevertheless it is possible to determine changes in the total fluids of the body by stating the *water balance*. The *water balance* represents the difference between total water intake and the total water output. The total water intake constitutes (1) the beverage water, (2) the preformed water of food, and (3) the water of oxidation of foods. Solid food usually contains more than 75 per cent of preformed water. The amount of water formed in the metabolism of food stuffs amounts to about 300 gm. a day. The total water output constitutes the water in the urine, and the insensible loss from the skin and lungs and occasionally loss in sweat, and through wounds. When a subject is weighed on a precision scale and correction is made for the total quantity of food and beverages ingested and the total quantity of urine and feces excreted, there is observed a steady insen-

TABLE 110  
EXTRACELLULAR FLUID VOLUME

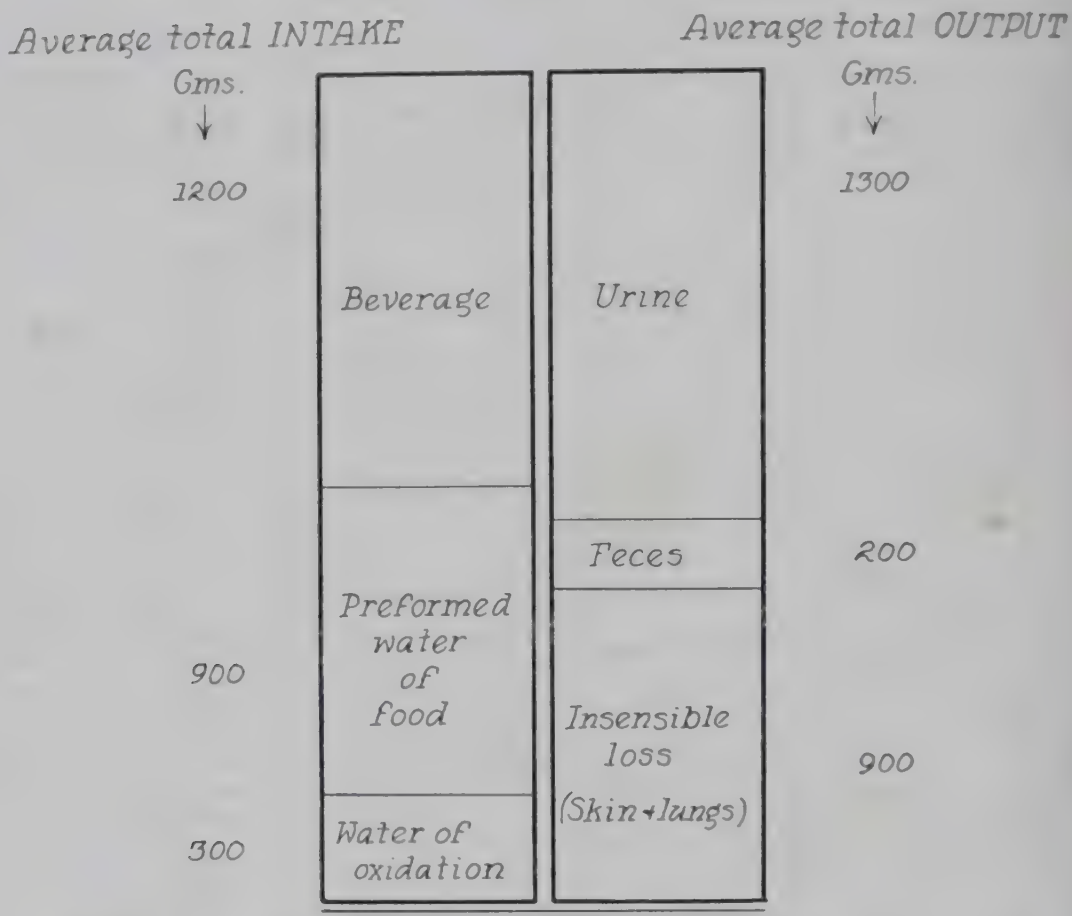
Subjects	Method	Range of Extracellular Fluid Volume		Investigator
		(Kg.)	(Per Cent of Body Weight)	
Determinations on males.....	Sucrose	8.4-17.4	13.1-29.2	Lavietes, Bourdillon and Klinghoffer (1936)
Determinations on males.....	Sulfocyanate	14.6-20.1	16.6-28.3	
Determinations on males.....	Sulfate	9.3-18.8	14.1-28.9	Crandall and Anderson (1934)
Determinations on males.....	Sulfocyanate	...	21-26	
Determinations on males.....	Bromide	...	23.2-30.9	Brodie, Brand and Leshin (1939)
Determinations on male.....	Sulfocyanate	....	27.1	Moore (1946)
	Radio sodium	....	26.5	

loss of weight amounting to about 900 gm. a day. The insensible loss of weight represents the water evaporated from the skin and lungs plus the difference in weights of oxygen inhaled and of carbon dioxide exhaled. On the histogram (Fig. 48a) are indicated average intake of water and average output of water when there is perfect water balance. If the water output is less than the intake, the water balance is obviously positive; when it is greater, it is negative. It is apparent, when the various components are considered, that water balance cannot be estimated by the common clinical practice of comparing the volume of urine with the quantity of fluid ingested. To do this would be to disregard a large proportion of both the water intake and the water output. Normally, the beverage intake and the urinary output may approximate each other, but this need not necessarily happen. It is probable that the clinical

estimation of the water balance is most easily obtained by measurement of the daily change in body weight.

It is desirable to mention briefly some of the mechanisms regulating the normal transfer of body fluids. Such transfers are governed in large part by

### Water Balance



$$\text{WATER BALANCE} = \text{WATER}_{\text{TOTAL INTAKE}} - \text{WATER}_{\text{TOTAL OUTPUT}}$$

*Grams of water yielded per 100 gm. of foodstuff*

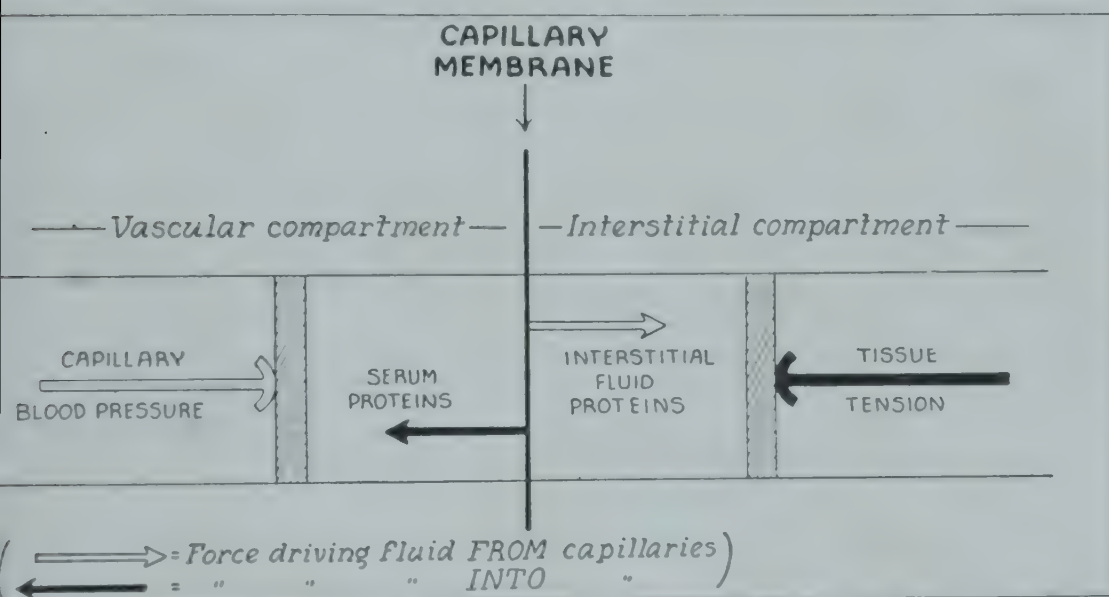
Fat - - - 107.1      Protein - - 41.3

Starch - - 55.1      Alcohol - - 117.3

Fig. 48a. Average intake of water and average output of water when there is perfect water balance. (Sunderman, F. W.: *Am. J. Clin. Path.*, vol. 16.)

certain inherent tendencies of the organism, several of which might be emphasized: (1) Under normal conditions, the body tends to keep the volume of the different body fluids constant within narrow limits. (2) Under normal conditions, the body tends to maintain the concentrations of the solutes in each fluid constant within narrow limits. Although the components of the various

may differ strikingly from each other nevertheless the osmolar concentrations of solutes in each fluid tend to remain constant. The maintenance of constant osmolar concentration is obviously aided by the free movement of water through the membranes. (3) The body fluids tend to establish osmotic equilibrium, or, in other words, to become isotonic with each other. This, obviously, tends to occur under all conditions, since water is freely movable through semipermeable membranes. (4) An additional mechanism regulating the interchange of fluids between the vascular and interstitial compartments is diagrammatically represented in Figure 48b, in accordance with the Starling hypothesis.<sup>17</sup> The length of the arrow has no significance in this diagram. There is a continuous interchange of water, electrolytes and nonelectrolytes between the blood and the tissue spaces through the capillary membranes. The capillary pressure tends to drive the fluid out of the capillaries, whereas the serum



48b. Colloidal osmotic pressure and hydrostatic pressure in the interchange of fluids across the capillary membrane. (Sunderman, F. W.: Am. J. Clin. Path., vol. 16.)

proteins, which are unable to escape through the capillary walls, tend to draw fluids back into the capillaries. On the other hand, the interstitial fluid proteins, which are normally of low concentration, tend to draw the fluids from the capillaries. The pressure exerted by the elastic subcutaneous tissues and designated on the figure as "tissue tension" is a factor of importance in driving fluids back into the capillaries. The forces driving fluid from the capillaries are the capillary blood pressure and the interstitial fluid proteins; the forces driving fluid into the capillaries are the serum proteins and the tissue tension. Under normal circumstances, a perfect balance is maintained between the inflow and outflow of fluid through the capillary membrane. However, under pathological conditions, such as edema and ascites, transudation exceeds absorption. Estimations of the sodium and potassium contents of the urine are also made as a means of estimating the proportions of water derived from the extracellular and intracellular compartments. These estimations are calculated on

the approximation that the potassium is wholly within the cells and the sodium without. This approximation is not entirely correct, for in the case of sodium, for example, only about 80 per cent is contained in the extracellular fluid.

BODY SECRETIONS

TABLE 111  
VOLUMES OF SECRETIONS PER DAY  
(Shohl, 1939)<sup>18</sup>

	Liters
Saliva . . . . .	1.0- 1.5
Gastric juice . . . . .	3.0- 5.0
Bile . . . . .	0.5- 1.0
Pancreatic juice . . . . .	0.8- 1.0
Intestinal juices . . . . .	2.0- 3.0
Total . . . . .	7.3-11.5

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Chapter 21

THE LYMPH

LYMPH and the fluid in the tissue spaces, the so-called interstitial fluid, similar in composition to, and to some extent resemble, blood plasma (see 112). The protein concentration of lymph or interstitial fluid is much less than that of plasma or serum. Stead and Warren<sup>3</sup> found that fluid obtained by needle puncture from the subcutaneous tissues of normal subjects contained an average of 0.24 gm. of protein per 100 ml. These workers also found that increase of the venous pressure in the leg to 30 mm. of mercury produced fluid containing from 0.4 to 1.3 gm. of protein per 100 ml. The albumin-globulin ratio in lymph and interstitial fluid is usually increased above that of plasma. Ratios as high as 4 to 1 are reported. This, theoretically, might be due to a preferential escape of the smaller albumin molecules through the capillary wall into the interstitial spaces. The fibrinogen concentration of lymph is usually lower than that of plasma.

Presumably, owing to the lower concentration of serum proteins and therefore of the calcium bound to protein, values of the total calcium in lymph are lower than those found in serum.

The cells contained in lymph are mostly lymphocytes, which in the lymph of the thoracic duct may vary from 1000 to 20,000 per cubic millimeter (dog). The composition of lymph contained in the thoracic duct will vary according to the stage of the digestive processes. After the ingestion of a fatty meal the intestinal lymph becomes white or "milky" and is termed "chyle." Chyle is essentially lymph containing from 5 to 15 per cent of emulsified fat. The protein concentration of chyle may be increased to 2 or more per cent.

TABLE 112

COMPARISON OF THE CONCENTRATION OF SOME OF THE CONSTITUENTS IN PERIPHERAL (CERVICAL) LYMPH AND BLOOD PLASMA OF THE DOG UNDER NORMAL CONDITIONS  
(Heim, 1933)<sup>2</sup>

	Protein Kjeldahl (Per Cent)	N P N (Mg. per 100 Cc.)	Urea (Mg. per 100 Cc.)	Uric Acid (Mg. per 100 Cc.)	Creat- inine (Mg. per 100 Cc.)	Sugar (Mg. per 100 Cc.)	Amino Acids (Mg. per 100 Cc.)	Chlor- ides as NaCl (Mg. per 100 Cc.)	Phosphorus		Calcium Mg. per 100 Cc.)
									Total (Mg. per 100 Cc.)	Inor- ganic (Mg. per 100 Cc.)	
Age e...	6 18 (5 54- 7 23)	32 6 (21 1- 46 0)	21 7 (17 9- 28 0)	Trace ....	1 37 (1 22- 1 54)	123 0 (112 0- 143 0)	4 90 ....	678 (649- 721)	22 0 (18 3- 26 1)	5 6 (4 4- 6 9)	11 70 (10 85- 12 95)
Age e...	3 32 (1 38 4 57)	34 8 (19 8- 45 4)	23 5 (19 8- 33 0)	Trace ....	1 40 (1 28- 1 49)	132 2 (107 0- 144 0)	4 84 ....	711 (690- 730)	11 8 (10 2- 13 7)	5 9 (4 7- 7 3)	9 84 (8 93- 10 84)

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## Chapter 22

# ENZYMES AND MISCELLANEOUS CONSTITUENTS OF THE BLOOD

### PHOSPHATASE

ON THE BASIS of activity in different  $pH$  ranges, essentially four types of phosphoesterases of biological significance have been described: (a) an alkaline phosphatase with optimal activity at about  $pH$  9.3, found in kidney, bone, ossifying cartilage, intestine, mammary gland, lung, spleen, blood, serum, leukocytes, adrenal cortex and seminiferous tubules; (b) a phosphatase with optimal activity at about  $pH$  6, occurring in mammalian erythrocytes and *Saccharomyces* yeast; (c) a phosphatase with optimal activity at  $pH$  5, found in spleen, pancreas, kidney, prostate, serum and rice bran; and (d) a phosphatase with optimal activity at about  $pH$  3 to 4, obtained from taka diastase and *Aspergillus oryzae*.

Although various types of phosphatases are present in body tissues, there is probably not an absolute specificity in regard to their actions, and most of tissue phosphatases are capable of hydrolyzing almost any monophosphoric acid ester.

Lawaczek<sup>15</sup> and Martland, Hansman and Robison<sup>17</sup> independently demonstrated the presence of phosphatase in serum and plasma. Kay<sup>12</sup> showed that the plasma phosphatase was most active in alkaline substrates and apparently identical with the phosphatase occurring in bone.

To distinguish phosphatase activity on the acid side of neutrality from activity on the alkaline side, Folley and Kay refer to the former as "acid" phosphatase; the usual phosphatase in serum, in contradistinction, is referred to simply as "phosphatase" or "alkaline" phosphatase. Investigations of acid phosphatase in serum indicate that this "phosphatase" is probably identical with that reported by Kutscher and his co-workers<sup>13, 14</sup> in the prostate gland; Gutman and his associates<sup>11</sup> in skeletal metastases from prostatic cancer; Hansmann and Riedel<sup>1</sup> in liver and kidney; and by Davies<sup>5</sup> in the spleen.

The optimal  $pH$  of the reaction mixture in measuring the alkaline phosphatase of serum with sodium B-glycerophosphate as the substrate is within a  $pH$  range of 9.1 to 9.7, according to Shinowara, Jones and Reinhart.<sup>20</sup> The slopes of the activity curve on either side of this range are steep, so that they recommend that the  $pH$  of the serum substrate mixtures be adjusted to a  $pH$   $\pm 0.15$  at  $37^\circ C$ . In addition, they confirm the observations of Gutman and Gutman<sup>16</sup> that for the measurement of acid phosphatase in serum, the optimal  $pH$  is  $5.0 \pm 0.15$  at  $37^\circ C$ .

Because of certain apparent advantages in measuring phosphatase by the Shinowara, Jones and Reinhart method, the definition of their unit of phosphatase activity is as follows:

phatase activity is quoted: "Each unit of serum phosphatase activity is equivalent to 1 mg. of phosphorus as phosphate ion liberated during 1 hour of acid incubation at 37° with a substrate containing sodium B-glycerophosphate, hydrolysis not exceeding 10 per cent of the substrate; and at optimum pH of the reaction mixture, for 'acid'  $5.00 \pm 0.15$  and for 'alkaline'  $9.30 \pm 0.15$ ."

The optimal activity for the phosphatase contained in erythrocytes is between pH 5.8 and 6.0; however, the enzyme continues to manifest activity in substrates of pH 5.0 and below. When estimating "acid" phosphatase in serum, Gutman and Gutman<sup>10</sup> point to the importance of keeping the serum free of hemolysis, since hemolyzed red cells liberate erythrocyte phosphatase into the serum and thus may give false high values for the estimation of serum "acid" phosphatase.

TABLE 113  
NORMAL VALUES FOR SERUM PHOSPHATASE  
(Sunderman, 1942)<sup>21</sup>

<i>Acid</i>		<i>Alkaline</i>				<i>Method</i>
Adults		Adults		Children		
Maxi- mum	Mini- mum	Maxi- mum	Mini- mum	Maxi- mum	Mini- mum	
Units	Units	Units	Units	Units	Units	
1.1	0.0	8.6	2.2	...	...	Shinowara, Reinhart and Jones
0.4	0.0	4.0	1.5	12.0	5.0	Bodansky
		15.0	10.0	40.0	35.0	Cayla
		7.9	3.2	11.0	3.4	Jenner-Kay
		0.21	0.10	0.34	0.17	Kay
		13.1	3.7	20.0	15.0	King-Armstrong
3.25	0.0	...	...	...	...	King-Armstrong (Gutman's modification)
		5.5	3.0	...	...	Roberts

Gomori<sup>7</sup> has described a method for demonstrating phosphatase in tissue sections. The phosphatase may be preserved by alcoholic fixation and subsequent imbedding in celloidin or paraffin. If the embedded tissues are incubated with an alkaline substrate of sodium glycerophosphate, sodium barbital and calcium nitrate, then calcium phosphate is formed at the site of phosphatase activity and may be visualized in the sections. By this method of demonstration phosphatase was found in epithelial as well as connective tissue elements. Sites of tissues and cells richest in alkaline phosphatase include the small intestines, urinary bladder, mammary gland, kidney, adrenal cortex, seminiferous tubules, ossifying cartilage, embryonal perichondrium, medium-sized arteries and the capillary endothelium of certain organs.

SERUM (PLASMA) AMYLASE\*

values for the amylase activity in normal blood plasma or serum depend on the type and amount of substrate used, the length of time of enzymatic reaction, and the temperature of the mixture during the incubation period. In usual clinical methods serum is mixed with starch. The amylase of the serum saccharifies starch, and the degree of saccharification is measured by the amount of reducing substances (after incubation of the serum-starch mixture) obtained in the serum alone. Normal values based upon this principle are given in Table 114. Additional values with other methods are given in Chapter 33.

TABLE 114  
NORMAL RANGE OF AMYLASE ACTIVITY OF SERUM (PLASMA)

Range	Investigator
Sugar (Glucose) per 100 Ml. of Plasma	
70-200	Elman (1937)
80-150	Somogyi (1938)
40-175	Lewison (1941)
70-217	Myers et al. (1944)*
40-145 (15 min. incubation)	Andersch (1946)
95-250 (30 min. incubation)	

Myers and his co-workers<sup>25</sup> express activity in terms of percentage of normal. The milligrams of sugar formed per milliliter of plasma are multiplied by 55 to give the percentage of normal. The average value obtained in their series was 182 mg. of sugar per 100 ml. of serum plasma, ∴  $1.82 \times 55 = 100$  per cent.

The range of values is apparently not affected by age, sex, diet or vitamin deficiency.

The amylase of whole blood is contained almost entirely in the plasma; therefore a value for whole blood would be approximately 60 per cent of that for serum or plasma.

Little amylase activity is observed (5 to 35 Somogyi units) during the neonatal period. During the first three days of life slightly higher values are found which may represent a persistence of enzyme supplied by the mother.

KETONE BODIES OF BLOOD

The ketone bodies include acetoacetic and beta hydroxybutyric acids and acetone. Concentrations are reported in terms of either beta hydroxybutyric acid or acetone, depending on the preference of the analyst. Normal subjects are postabsorptive, but who have not been without food for an unduly long period, show values ranging from 0 to 1.0 mg. of ketone bodies as acetone. The blood corpuscles contain less acetone than serum, and concentrations of blood ketones are about 25 per cent lower than those of serum. Sixty to 70 per cent of the total ketone body of blood is beta hydroxybutyric acid. Acetone is present in much smaller concentrations than the two acids.

\*For Serum Lipase, see Chapter 33.

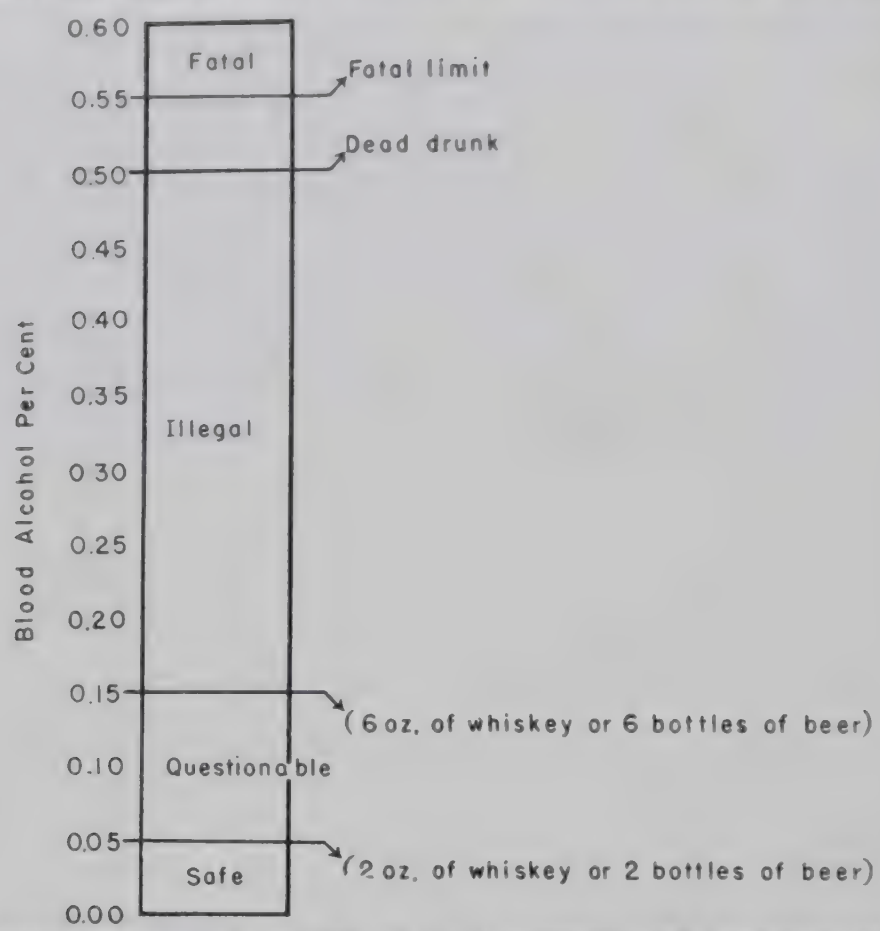


Fig. 49. Blood alcohol levels. (Harger, R. N.: J. Criminal Law & Criminology, vol. 35.

TABLE 115

RANGE OF CONCENTRATIONS OF MISCELLANEOUS CONSTITUENTS OF NORMAL BLOOD OR PLASMA

Constituent	Material	Range	Average Value	Investigator
Adrenaline . . . . .	Blood	Less than 0.001 microgram per ml.	....	Bloor and Bullen (1938)
Adrenaline-like substance . . . . .	Blood	About 25 micrograms per 100 ml. 4.1-9.6 micrograms per 100 ml.	.... 6.8	Bloor and Bullen (1938) Jørgensen (1945)
Carotenoids . . . . .	Serum	100-300 int. units/100 ml.	....	Josephs (1939)
Indican . . . . .	Serum	0.026-0.085 mg. per 100 ml.	....	Townsend-Sharlit
α-ketoglutaric acid . . . . .	Blood	80-100 mg. per 100 ml.	....	D'Ambrosio and Villan
Lactic acid . . . . .	Arterial blood	5.9-19.1 mg. per 100 ml. 7.7-22.0 mg. per 100 ml.	9.9 S. D. 2.6 11.5 S. D. 2.7	(1946) Gibbs et al. (1942)
Pyruvic acid . . . . .	Blood	0.5-1 mg./100 ml.	0.76 S.D. 0.173	Gibbs et al. (1942)
Pyruvic acid . . . . .	Plasma	0.7-1.2 mg./100 ml.	....	Klein
Citric acid . . . . .	Blood	1.33-2.28 mg./100 ml.	....	Wolcott and Boyer
	Plasma	1.60-2.66 mg./100 ml.		
Bromide . . . . .	Blood	0.7 to 1.0 microgram per 100 ml.	....	Gray and Moore

## BLOOD ALCOHOL

though strictly not normal, the ingestion of alcohol is so common that inclusion of Figure 49, indicating the concentrations of blood alcohol after various states of imbibition, would not seem inappropriate.

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# Chapter 23

## RÉSUMÉ OF PHYSICAL CHARACTERISTICS AND CHEMICAL COMPONENTS OF BLOOD AND SERUM

TABLE 116  
NORMAL VALUES FOUND IN AUTHOR'S LABORATORIES\*

	<i>Whole Blood</i>	<i>Corpuscles</i>	<i>Serum</i>	<i>Method</i>
g point depression° C.	....	....	0.535-0.555	Stadie and Sunderman
age of components (natocrit reading)	....	40-48	52-60	
on pH 38°C. Arterial	....	....	7.30-7.41	Stadie
Venous	....	....	7.27-7.37	
tive index 20°C.	....	....	1.3485-1.3505	Abbe
gm. per 100 gm.	18.99-20.89	34.61-35.19	8.77-9.01	Drying to constant weight
e gravity, 20°C/20°C.	....	....	1.024-1.027	Pycnometer
ty (water = 1)	4.4-5.5	....	1.7-2.1	Oswald
	3.6-5.4	....	1.7-2.0	Hess
e(ml./kg. of body wt.)	70-80	....	40-46	Sunderman and Austin
gm. per 100 gm.	79.1-91.0	64.2-65.4	91.3-92.3	Sunderman

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TABLE 117

RÉSUMÉ OF CHEMICAL COMPOSITION OF BLOOD  
(Normal Values Found in Author's Laboratories)

<i>Substance</i>	<i>Whole Blood</i>	<i>Serum</i>	<i>Method</i>
Albumin (see <i>Protein</i> )			
Amino nitrogen (see <i>Protein</i> )			
Ammonia (calculated as $\text{NH}_3$ ) mg./100 ml.	.....	0.14-0.3	Morgulis and Jahr
Amylase-units/100 ml.	.....	15-35	Somogyi
Ascorbic acid (mg./100 ml.)	.....	0.7-1.5	Farmer and Abt
Base proteinate: B Pr = 0.97 (Pr. gm./ml.) pH = 5.26	.....	12-16	Hastings, Salvesen, Sendroy and Van Slyke
Base—Total (mEq./L.)	.....	142-149.3	Hald; Sunderman
Bilirubin—Total (mg./100 ml.)	.....	0.1-0.8	Powell
Direct (mg./100 ml.)	.....	0.1-0.2	
Indirect (mg./100 ml.)	.....	0 -0.6	
Bilirubin—Van den Bergh	.....	0.1-0.5	McKee and Keefer
Direct (mg./100 ml.)	.....	Negative	
Indirect (mg./100 ml.)	.....	0 -0.5	
Calcium (mEq./L.)	.....	4.5-5.5	Clark and Collip
as Ca. (mg./100 ml.)	.....	9-11	
Carotin (mg./100 ml.)	.....	0-0.1	Connor
Chlorides* (mEq./L.)	77-90	98.5-104.5	Wilson and Ball
as Cl (mg./100 ml.)	273-320	350-371	
as NaCl (mg./100 ml.)	445-526	576-612	
Cholesterol (see <i>Lipids</i> on page 188)			
$\text{CO}_2$ as $\text{BH CO}_2 - \text{H}_2 \text{CO}_3$ (Vol. %) (mEq./L.)	.....	60-70 26.6-31.6	Van Slyke and Neil
$\text{CO}_2$ Capacity† (volumes %)	.....	55-75	
$\text{CO}_2$ Content† (volumes %)	.....	45-65	
Copper (mg./100 ml.)	0.156-0.200	0.196-0.263	Tempsett
Creatine—as creatinine	3.0-7.0	1.0-2.0	Mod. Folin

\* The chloride concentration of the whole blood depends largely on the cell volume, as the cells contain approximately half as much chlorides as the serum.

† Blood collected under oil and allowed to clot.

TABLE 117—Continued

Substance	Whole Blood	Serum	Method
Iron (mg./100 ml.)	1-2	.....	Brown
	1.2-1.5	1.0-1.3	Mod. Folin
Lipids			
(see Proteins)			
Hemoglobin (see Chap. 6 and 16) (100 ml.)	12-17 (men) 11-15 (women)		
Index (units)	.....	4-6	Bernheim
		0.026-0.085	Townsend-Sharlit
Calcium (mg./100 ml.)	42-50	0.06-0.18	Wong
Calcium—as Mg. (mEq./L.) (mg./100 ml.)	..... .....	1.8-2.2 2.2-2.7	Briggs
Non-protein nitrogen (mg./100 ml.)	5-8	4-6	Folin
Ammonia nitrogen (mg./100 ml.)	0.1-0.2	.....	Nash and Benedict
Protein nitrogen (mg./100 ml.)	27.8-39.4	22-29	Pregl; Folin
Urea nitrogen (total gm./L.)	.....	9.6-11.2	Kjehldahl; Pregl
Urea nitrogen (mg./100 ml.)	8.9-15.2	9.6-17.3	Karr; Cullen and Van Slyke
N—N. P. N. (ratio)	0.35-0.5	0.45-0.6	
Uncombined N (mg./100 ml.)	5-10	1-8	By difference
Oxygen capacity—(Vol.%) Female	17-21	.....	Van Slyke and Neil
Male	18-22		
Oxygen content—(Vol.%) Arterial	15-22	.....	Van Slyke and Neil
(Vol.%) Venous	11-16		
Alkaline phosphatase (see Table 113)			
Phosphorus—Total (mg./100 ml.)			
Adults	.....	8-18	Stearns and Warweg
Infants	.....	5-14	Warweg
Phosphorus—Inorganic (mg./100 ml.)			
Adults	.....	3.2-4.3	Fiske and Suttarow
Infants	.....	4-7	
Adults (mM/L.)	1.03-1.4	1.03-1.4	
B <sub>2</sub> HPO <sub>4</sub> + BH <sub>2</sub> PO <sub>4</sub> (mEq./L.)	.....	1.6-2.7	

TABLE 117—*Continued*

<i>Substance</i>	<i>Whole Blood</i>	<i>Serum</i>	<i>Method</i>
Phosphatides (see <i>Lipids</i> )			
Potassium—as K (mEq./L.)	.....	3.8–4.3	Consolazio and T bot; Shohl Bennett
(mg./100 ml.)	.....	14.8–16.8	
Protein: Albumin (gm./100 ml.)	.....	3.3–4.3	Howe
Albumin-globulin ratio	.....	1.6–2	
Fibrinogen (gm./100 ml.)	.....	0.3–0.4*	Cullen and Van S
Total (gm./100 ml.)	.....	6–7	Kingsley; Pregl
Sodium—as Na (mEq./L.)	.....	133.6–136.3	Barber and Koltod
(mg./100 ml.)	.....	307.5–316	
Sugar (total reducing substance)			
Arterial (mg./100 ml.)	80–110	80–110	Benedict; Sunder- man and Razek
Venous (mg./100 ml.)	70–100		
Venous (mg./100 ml.)	85–115	.....	Folin and Wu
Sulfur: Inorganic (mEq./L.)	.....	0.3–0.7	Denis
(mg./100 ml.)	0.1–1.1	0.5–1.1	
Ethetal sulfate (mg./100 ml.)	0.1–1.0	0.1–1.0	
Neutral sulfur (mg./100 ml.)	2.2–4.5	1.7–3.5	
Urea (mg./100 ml.)	18.9–32.3	20.4–36.8	Karr
Urea nitrogen (mg./100 ml.)	8.9–15.2	9.6–17.3	Karr
Uric acid (mg./100 ml.)	2–4		Brown
	1–3	2–4	Folin
Van den Bergh Reaction (see <i>Bilirubin</i> )			
Lipids:			
Cholesterol—Total (mg./100 ml.)	170–190	150–190	Bloor; Sunderman and Razek
		160–210	
Cholesterol—Free (mg./100 ml.)		60–70	Bloor; Sunderman and Razek
Cholesterol—Esterified (mg./100 ml.)		90–114	Bloor; Sunderman and Razek

\* Plasma.

TABLE 117—Continued

Substance	Whole Blood	Serum	Method
Cholesterol—Esters cholesterol and stearate (mg./100 ml.)	.....	150-193	
Cholesterol—Lipid (mg./100 ml.)	.....	8-10	
Phosphatides (mg./100 ml.)	.....	135-169	Stearns and Warweg
Phosphatides (mg./100 ml.)	.....	208-260	Stearns and Warweg
Continued Fatty acids (mEq./L.)	.....	14.2-17.3	Mann and Gildea
Phosphatides (mg./100 ml.)	.....	380-465	
Neutral fats (mg./100 ml.)	.....	150-250	Calculated
Phosphatides (mg./100 ml.)	.....	500-600	

*Equations for Calculating Blood Lipids*

Phosphatides =  $23.5 \times (\text{total lipid P})$ .

Esterified cholesterol = (total cholesterol)—(free cholesterol).

Cholesterol esters =  $1.69 (\text{esterified cholesterol})$ .

Neutral fat C = (total lipid C— $15.5 (\text{lipid}) + 0.839 (\text{free cholesterol in } 1.40 (\text{esterified cholesterol}))$ .

Neutral fat =  $1.32 (\text{neutral fat C})$ .

Total lipids = phosphatides + free cholesterol + cholesterol esters + neutral fat.

Total lipids =  $1.3 (\text{total lipid C})$ .\*

Phosphatides =  $\text{lipid P} \times \frac{805.7}{31}$ .

805.7 = mol. wt. of lecithin

31 = atomic wt. of phosphorus

Fatty acids in blood occur in combination with glycerine as neutral fats, also in phosphatides and cholesterol esters.

Fatty acids mEq L  $\times 26.9 = \text{fatty acids (mg./100 ml.)—as tripalmitin.}$

Calculations—Equations 1 to 7 after Page, Kirk, Lewis, Thompson, Van Slyke: J. Clin. Chem., 111, 613, 1935.



Section IV

RESPIRATORY SYSTEM

(Normal Values for Respiratory Tract)



## Chapter 24

# RESPIRATORY SYSTEM

## LARYNX

AL DIMENSIONS AND POSITIONS OF THE LARYNX. From six to twelve years of age the tip of the epiglottis lies just above the level of the fibrocartilage between the odontoid process and the body of the axis and descends between the vertebral bodies and two intervertebral fibrocartilages by the time of maturity. In adult males it lies at the level of the fourth, fifth and sixth cervical vertebrae. It is slightly higher in women.

TABLE 118

AVERAGE MEASUREMENTS OF THE ADULT LARYNX

	Males (Mm.)	Females (Mm.)
Length.....	44	36
Transverse diameter.....	43	41
Anteroposterior diameter.....	36	26
Circumference.....	136	112
Length of the glottic chink.....	23	17
Anterior "vocal portion" of glottic chink.....	15.5	11.5
Posterior "respiratory portion" of glottic chink.....	7.5	5.5
Posterior separation of vocal cords.....	8-12	8-12
Thyroid notch to level of vocal cord.....	8.5	6.5
Bottom of thyroid to level of vocal cord.....	10.5	8.0
Internal diameter of cricoid.....	19	

The ventricular bands (false vocal cords) are about 3.5 mm. above the vocal cords. Between them is the aperture of the laryngeal ventricle, from 3 to 4 mm. wide. The ventricle may extend upward beneath the ventricular bands as much as 15 mm.

## TRACHEA AND BRONCHI

TRACHEA. The trachea consists of a framework of sixteen to twenty cartilaginous crescents, connected with each other by a dense layer of connective tissue, the "ligamentum annularia." The *carina trachea* is a prominent ridge running anteroposteriorly across the bottom of the trachea between the origins of the two bronchi. The length of the trachea is 12 cm. in an adult male; 7 cm. in a young man; 4 cm. in an infant. The diameter in male adults is 15 to 22 mm.; in children, 8 to 11 mm.; in infants, 6 to 7 mm. It moves slightly upward during swallowing and downward with inspiration as much as 1 cm.<sup>10</sup>

BRONCHI. The right main bronchus enters the lung at the level of the fifth thoracic vertebra. Its transverse diameter varies from 13.5 to 21 mm. The

azygos vein arches over it from behind, and the right pulmonary artery is first below and then in front of it.

The left main bronchus enters the lung at the level of the sixth thoracic vertebra. Its transverse diameter varies from 12.5 to 17 mm. The aortic arch is above it; the thoracic duct, descending aorta, and esophagus are behind it; the left pulmonary artery is above and then in front of it.

TABLE 119  
CADAVERIC DIMENSIONS OF THE TRACHEOBRONCHIAL TREE  
(Modified from Jackson and Jackson, 1945)

	Male	Female	Child	Infant
Diameter of trachea . . . . .	14 × 20 to 25 mm.	12 × 16 mm.	8 × 10 mm.	6 × 7 mm.
Length of trachea (16-20 cartilages) . . . . .	12 cm.	10 cm.	6 cm.	4 cm.
Length of right bronchus (6-8 cartilages) . . . . .	2.5 cm.	2.5 cm.	2 cm.	1.5 cm.
Length of left bronchus (9-12 cartilages) . . . . .	5 cm.	5 cm.	3 cm.	2.5 cm.
Length of upper teeth to trachea . . . . .	15 cm.	13 cm.	10 cm.	9 cm.
Length (total) to secondary bronchus . . . . .	32 cm.	28 cm.	19 cm.	15 cm.

The cross section area of the right bronchus is to the left bronchus as 100 is to 77.9.

The average angle of divergence of the main bronchi at the tracheal bifurcation is 74.5 degrees.

BRONCHOPULMONARY SEGMENTS

For practical purposes the lungs may be divided into lobes which are fairly constant and well recognized, and each lobe into segments. These segments are supplied by the principal subdivisions of the bronchus entering that lobe. There is a fair degree of constancy in these bronchial subdivisions, both with respect to their point of origin in the tracheobronchial tree and to the part of lung which they supply; hence the term "bronchopulmonary" segment. There is no standard nomenclature for these segments, or for the bronchial subdivision which supplies them; nor is there a standard definition of what constitutes a segmental bronchus.

Figure 50, with the nomenclature which Jackson and Huber<sup>5</sup> have suggested, is drawn as though one were standing at the head of a patient dorsally recumbent. This is the relationship of endoscopist to patient during bronchoscopy. The circles represent the position of the bronchial subdivisions as observed bronchoscopically at the indicated levels of the tracheobronchial tree.

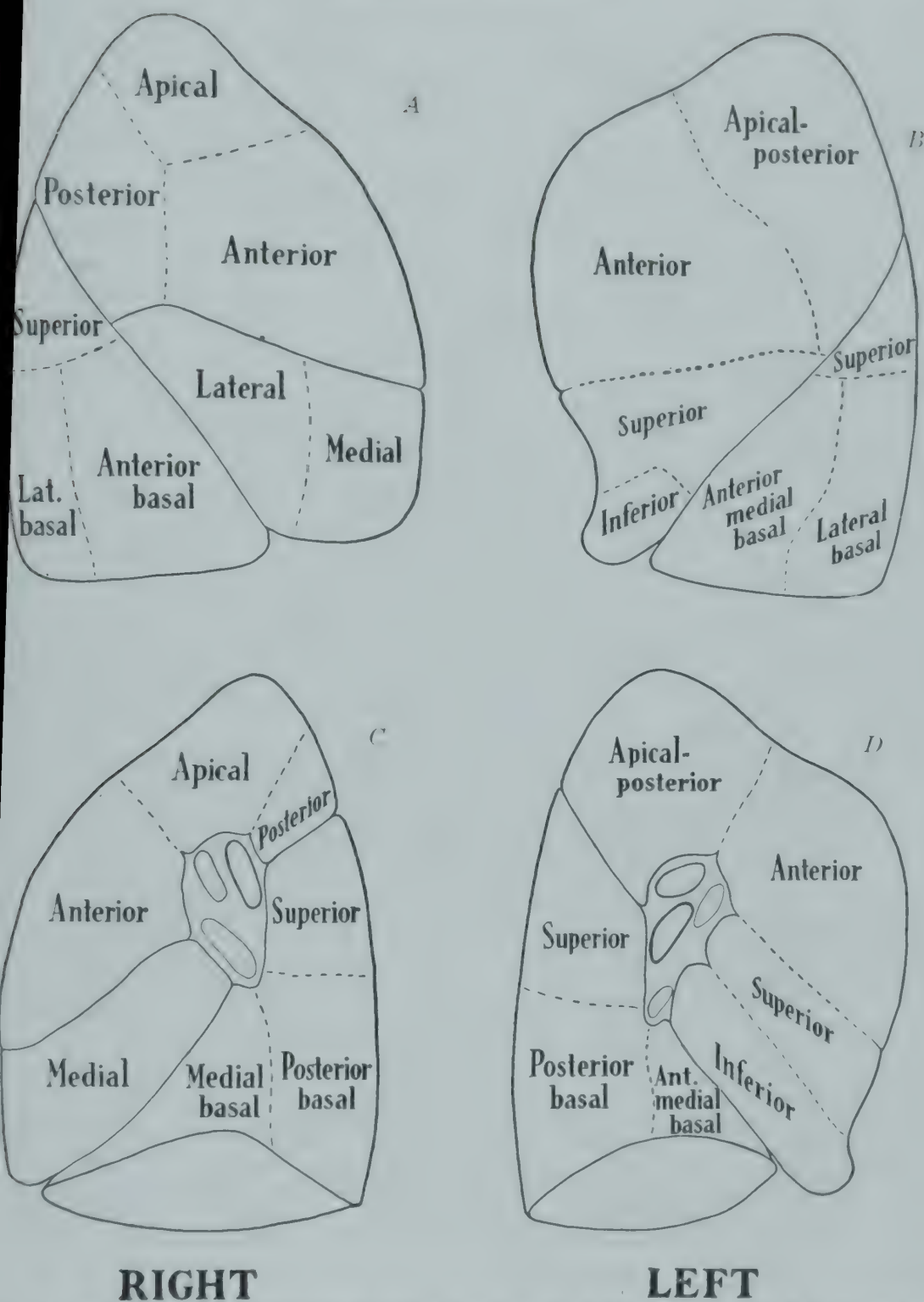


Fig. 50. The bronchopulmonary segments, shown in both anterolateral (A and B) and medial (C and D) aspects. The terminology used here, as well as in Figure 50, is that suggested by Jackson and Huber in *Diseases of the Chest*, volume 9. (Jackson and Jackson: *Diseases of the Chest*, Throat and Ear, 1946.)

### THE CHEST

At birth the chest is cylindrical. It gradually becomes elliptical in shape by the twentieth year of age and tends to roundness again as age advances.<sup>1</sup>

**THORACIC INDEX.** The thoracic index is the ratio of the depth to the width of the chest. It is usually expressed as the percentage of the former relative to the latter. The measurements are usually made at the level of the nipples. The following formula may be used for comparing data with the figures given in Table 120:

$$\frac{\text{Depth of chest}}{\text{Width of chest}} \times 1000 = \text{Thoracic index}$$

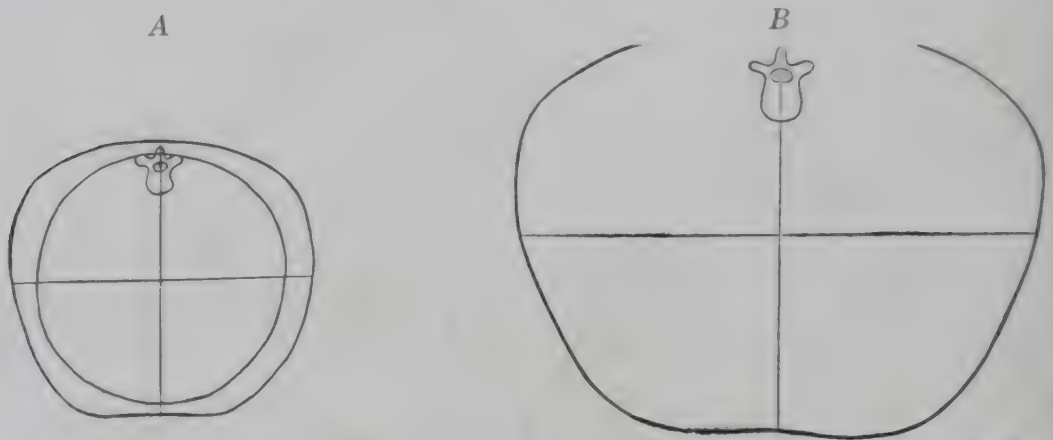


Fig. 51. *A*, Transverse section of an infant's chest, cylindrical in shape. *B*, Transverse section of an adult's chest, elliptical in shape. (Norris, G. W., and Landis, H. R. M.: *Diseases of the Chest*.)

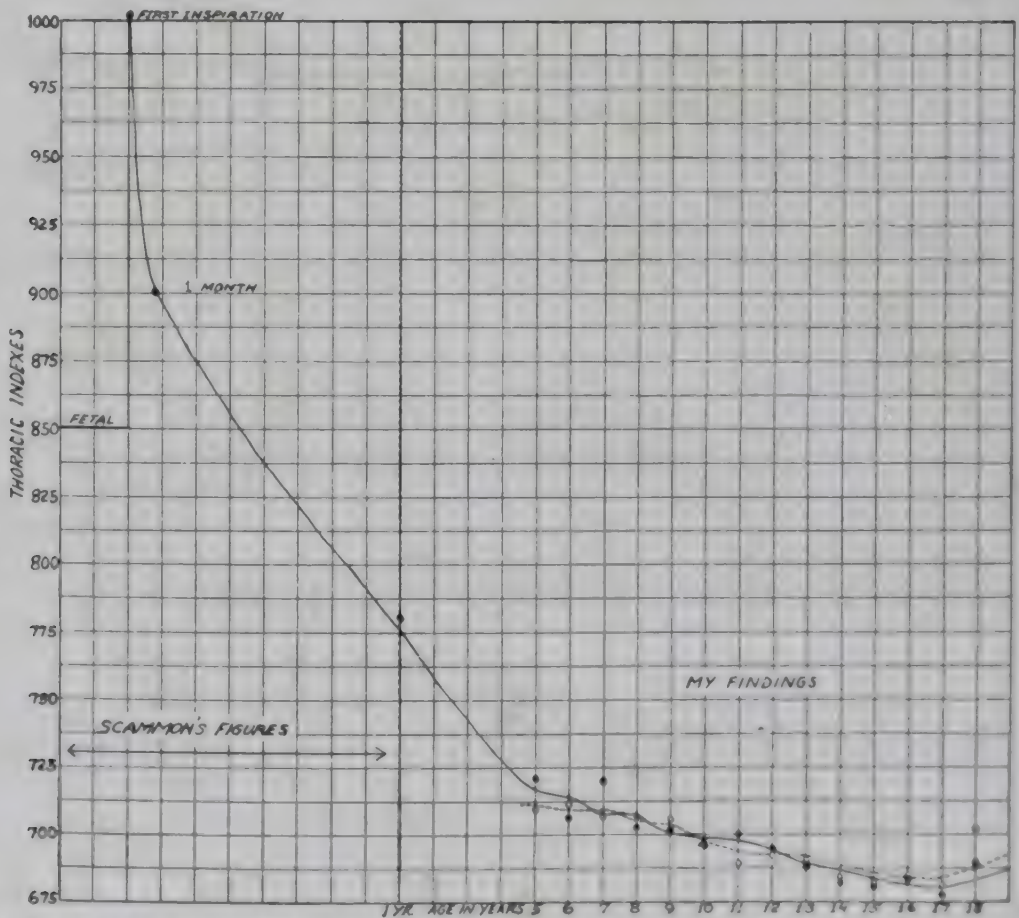


Fig. 52. Graph showing changes in the thoracic index from the fetal period to the age of 18 years. The circles represent the average thoracic index for each age group. The solid line and black dots indicate boys; the broken line and white dots, girls. (Weisman, S. A. *Am. J. Dis. Child.*, vol. 48.)

TABLE 120  
THORACIC INDICES OF 18,557 SCHOOL CHILDREN  
(Weisman, 1934)<sup>11</sup>

Number of Cases		Median		Average		Average Deviation		Standard Deviation		Probable Error	
Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
266	238	727	709	720	710	3.9	3.2	1.54	1.52	±0.063	±0.066
784	733	707	719	707	717	3.0	3.57	1.39	1.36	±0.033	±0.034
722	826	711	706	718	707	3.47	3.4	1.44	1.41	±0.036	±0.033
878	903	703	706	703	707	3.2	3.1	1.32	1.30	±0.032	±0.028
886	935	703	703	702	706	3.3	3.2	1.33	1.11	±0.028	±0.024
915	905	694	692	697	697	3.3	3.6	1.24	1.44	±0.026	±0.032
871	843	700	692	700	691	3.7	3.5	1.45	1.42	±0.033	±0.033
829	850	699	694	697	695	3.8	3.6	1.59	1.56	±0.037	±0.035
733	788	683	690	689	693	3.9	4.2	1.56	1.70	±0.038	±0.040
935	854	681	684	682	684	3.9	3.9	1.61	1.68	±0.035	±0.038
880	730	681	680	681	682	4.0	4.2	1.60	1.65	±0.036	±0.041
500	339	673	681	684	685	4.46	4.3	1.76	1.73	±0.053	±0.090
194	141	679	681	678	681	4.4	4.3	1.65	1.50	±0.079	±0.085
45	34	679	802	690	704	4.5	4.6	1.88	1.77	±0.189	±0.205

POGRAPHY. To fix a standard of what constitutes a normal chest by to estimate either the existence or the degree of abnormal variations, is ssible.<sup>7</sup> For the purpose of description, the chest is divided into certain , as shown in Figures 53 and 54.

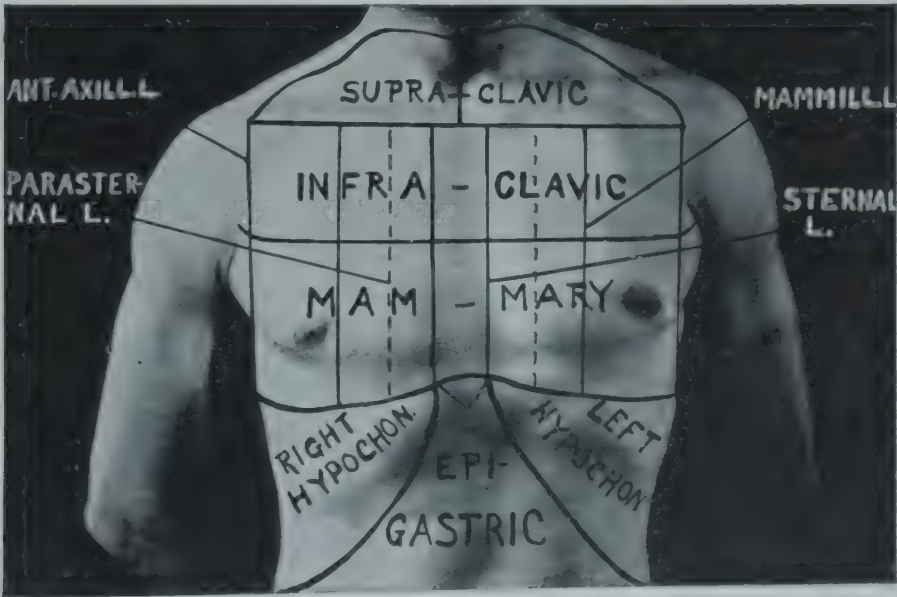


Fig. 53. Topography of the chest, anteriorly. For purposes of description, the chest is divided into certain regions which are shown in this illustration and in Figure 54. (Norris and Landis, H. R. M.: Diseases of the Chest.)

THE LUNGS

The lungs lie free in the two pleural cavities, attached only at the root and pulmonary ligaments. The right lung is divided into three lobes and the left into two lobes (see Fig. 50). For clinical purposes, and especially for radio-logic description, the lungs are divided into three zones: apical, middle and

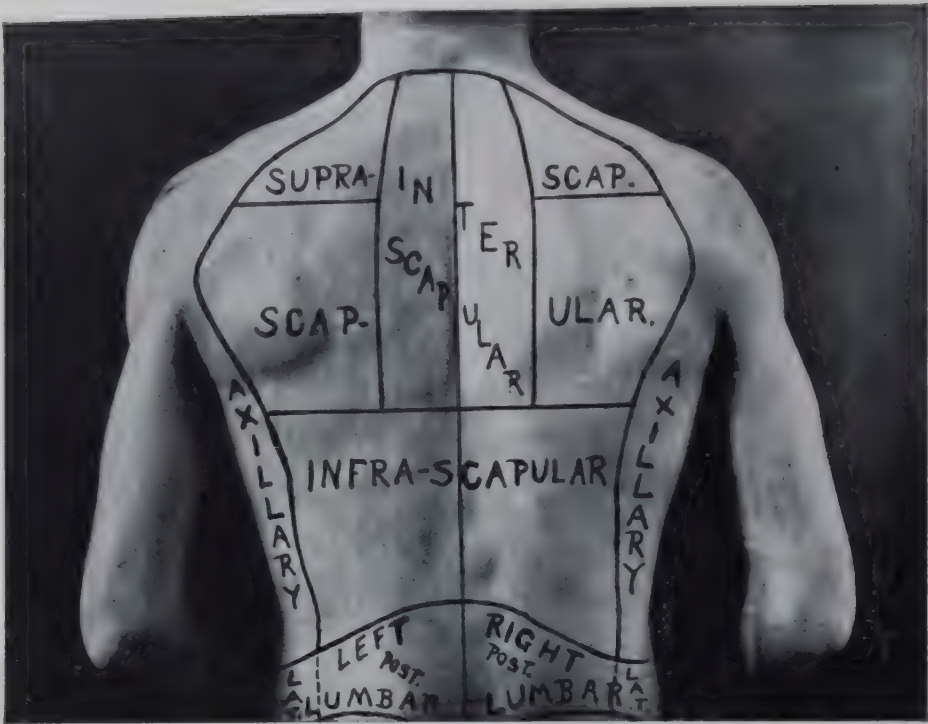


Fig. 54. Topography of the chest, posteriorly. (Norris, G. W., and Landis, H. R. M.: Diseases of the Chest.)

TABLE 121

AVERAGE MAXIMUM EXPIRATORY AND INSPIRATORY AND AVERAGE RELAXATION PRESSURES AT DIFFERENT LUNG VOLUMES WITH STANDARD DEVIATIONS

(Rahn et al., 1946)<sup>8</sup>

Macimum Expiratory Pressures		Maximum Inspiratory Pressures		Relaxation Pressures	
12 Male Subjects		11 Male Subjects		14 Male Subjects	
Volume (per Cent)	Positive Pressures (Mm. Hg)	Volume (per Cent)	Negative Pressures (Mm. Hg)	Volume (per Cent)	Pressures (Mm. Hg)
9.7	41.5 ± 13.4	3.9	86.0 ± 19.5	0	-19.2 ± 6.3
25.0	52.5 ± 20.8	21.7	74.6 ± 14.1	13.9	-8.5 ± 3.5
43.8	69.6 ± 19.7	34.8	63.3 ± 18.7	31.0	-1.3 ± 4.3
60.0	90.0 ± 21.5	55.6	56.8 ± 15.6	51.0	+4.1 ± 3.0
75.0	95.3 ± 17.6	75.7	44.8 ± 14.0	72.0	+10.5 ± 4.3
83.0	107.0 ± 16.3	91.0	23.6 ± 12.9	87.0	+14.9 ± 7.3
				100.0	+20.6 ± 5.2

Observations were grouped according to lung volumes, and the actual volumes within each group were averaged to give the recorded values. The groups chosen were as follows: 0%, 1-20%, 21-40%, 41-60%, 61-80%, 81-99% and 100%. All volumes are expressed in per cent of the vital capacity at ambient pressure. All measurements were made in the seated position.

INTRAPULMONARY PRESSURE. In the resting position of the chest the intrapulmonary pressure is atmospheric, but it varies rhythmically with the phases

ration, rising above atmospheric pressure during expiration and becoming subatmospheric during inspiration. The maximal negative pressure capable of being developed within the lungs by a forced inspiration, as when a strong effort is made, is from minus 40 to minus 50 mm. of mercury. When voluntary efforts are against a closed glottis, as in coughing, during muscular exertion with straining or during defecation or micturition, the intrapulmonary pressure is raised 10 to 40 mm. of mercury (see Table 121).

**INTRAPLEURAL (INTRATHORACIC) PRESSURE.** The pressure on the pleural surface of the lungs is less than that upon their alveolar surface; i. e., the intrapleural pressure is always subatmospheric. During quiet respiration it amounts to minus 6 mm. of mercury. During an ordinary expiration it is reduced to minus 2.5 mm. of mercury.

## RESPIRATORY RATE

Of all the factors concerned in the normal functioning of a living organism, respiration is probably the most essential.<sup>9</sup> The fundamental purpose of respiration is to assure for the organism an adequate supply of oxygen. In the higher breathing vertebrates, such as man, special organs (lungs) have been developed which provide an extensive surface through which the blood may readily come in contact with a sufficient quantity of the atmospheric air from which it absorbs oxygen and into which to excrete carbon dioxide. This is facilitated by the rhythmic movements brought about by contraction of voluntary muscles regulated by special nervous mechanisms. This part of the respiratory process, known as *external respiration*, is intimately coordinated with the other phases, namely, the transportation of oxygen from the lungs to the tissues and of carbon dioxide to the lungs, and the absorption of oxygen and elimination of carbon dioxide by the tissue cells (*internal respiration*).

The movement of air into and out of the lungs is accomplished by muscular action on the thoracic walls, which alternately increases the size of the thorax during inspiration and decreases it during expiration. The respiratory rhythm is regulated by the so-called *Hering-Breuer reflex*. This depends upon tension in the alveoli during inspiration; when a certain degree of tension is attained, the respiratory act is reversed and expiration occurs. The afferent impulses of this reflex are conveyed by the vagus. The efferent impulses are transmitted to the diaphragm by the phrenic nerve and to the intercostal muscles by the spinal nerves. The mechanism of respiration is under the regulation of an exceedingly sensitive respiratory center or centers in the midbrain. The thoracic cavity is enlarged during inspiration in all directions (vertical, anteroposterior and transverse), but not equally so. As a result of contraction of the diaphragm, the greatest enlargement is downward, the elevation of the ribs limits lateral expansion, while the forward and upward movement of the sternum is responsible for an increase anteriorly.

In contrast to inspiration, which is accomplished by active muscular contraction, normal expiration is passive. The walls of the chest fall back into their normal position as the ribs move downward and inward from elastic recoil. The

duration of expiration is slightly longer than that of inspiration; although in normal breathing the inspiratory vesicular murmur is longer than the expiratory.

The act of normal quiet breathing (*eupnea*) is accomplished without any conscious effort. When for any reason forced breathing becomes necessary, the individual becomes aware of the respiratory act (*dyspnea*). In any degree of dyspnea on inspiration, the contraction of the diaphragm and external intercostal muscles is increased, and the accessory muscles of inspiration (scaleni, sternocleidomastoid, pectoralis major) are called into play. Furthermore, the expiratory effort is increased by active contraction of the internal intercostals but especially by contraction of the muscles of the abdominal wall, which push the contents of the abdomen upward against the diaphragm and play a leading role in expiration.

TABLE 122  
RELATIONSHIP OF AGE, PULSE AND RESPIRATORY RATES, TO BODY TEMPERATURE  
(Norris and Landis, 1938)<sup>7</sup>

	Temperature (Degrees F.)	Pulse Rate (per Minute)	Respiratory Rate (per Minute)
Birth—2 years . . . . .	98	122	30
	102	141	43
	105	149	50
2-5 years . . . . .	98	114	26
	102	135	35
	105	161	44
5-9 years . . . . .	98	103	25
	102	128	30
	105	136	37
9-12 years . . . . .	98	89	24
	102	117	29
	105	136	31
Adult . . . . .	98	76	17
	102	106	27
	105	136	34

In a normal man at rest the respiratory rate varies from fourteen to eighteen rhythmical expansions and contractions per minute. Women exhibit a slightly higher rate, an average of twenty to twenty-two per minute. In the newborn the rate of respiration is more rapid (see Table 122). During the first few years of life it gradually slows down, but in the resting child up to the age of three years the rate of respiration may still vary from twenty to forty per minute. By the age of five years it drops to twenty-six per minute, and thereafter diminishes, reaching the adult rate in late childhood.

Under normal conditions there is a fairly constant ratio (ordinarily 4 or 4.5 to 1) between pulse rate and respiration (see Table 122). The rate and depth of respiration bear an inverse ratio to each other: the greater the

of breathing, the less the depth. The rate of respiration may be con- to some extent by will, but it is subject to modification by many external sture exerts a definite influence. *In a normal recumbent man the rate of ion is fourteen per minute; sitting, twenty per minute; erect, twenty-two*

TABLE 123

RATE OF RESPIRATION IN HEALTHY YOUNG INFANTS DURING SLEEP

Age	Range	Author
.....	27- 48	Vogt (1929)
1st day.....	24-116	Murphy and Thorpe (1931)
are.....	31-114	Shaw and Hopkins (1931)
1st week.....	24- 76	Deming and Washburn (1935)
1st day.....	24-120	Bauer (1940)

TABLE 124

TE AND VOLUME OF RESPIRATION ACCORDING TO DAYS OF LIFE AFTER BIRTH\* (Deming and Hanner, 1936)<sup>2</sup>

Rate per Minute		Depth of Inspiration, Ml.		Volume per Minute, Ml.		Volume per Pound per Minute, Ml.	
Range	Aver- age	Range	Aver- age	Range	Aver- age	Range	Aver- age
16 to 59	41	9.7 to 26.7	18.7	225.0 to 1186.9	734.0	38.1 to 190.4	106.0
27 to 82	43	11.6 to 24.9	18.3	436.1 to 1703.9	757.3	Only 1 sample	231.0
23 to 66	40	12.2 to 29.8	19.5	465.0 to 1003.2	816.8	94.2 to 142.8	123.3
26 to 66	43	11.3 to 24.2	19.0	581.7 to 1095.2	771.1	98.5 to 160.1	120.5
25 to 70	41	15.2 to 26.1	19.1	550.0 to 1452.5	776.4	92.0 to 215.2	115.1
26 to 51	40	10.9 to 29.8	19.7	561.1 to 900.9	781.9	93.8 to 139.0	122.4
28 to 59	44	14.3 to 22.9	18.9	490.2 to 1222.0	943.4	70.3 to 170.0	120.3
27 to 85	45	17.6 to 28.9	22.3	671.7 to 1835.1	983.4	97.4 to 248.8	141.0
32 to 80	49	13.4 to 26.8	20.9	681.5 to 1663.2	987.8	110.9 to 236.5	146.9
32 to 93	57	15.7 to 30.5	21.8	909.9 to 1483.9	1154.6	123.9 to 206.9	159.0
32 to 72	46	24.7 to 25.2	24.9	806.2 to 1774.3	1143.7	Only 2 samples	113.5
						110.4 and 116.5	

41 tracings on 18 normal infants during sleep. Day of birth.

minute. Respiration is less frequent in the morning than in the latter part day. During quiet sleep the rate is usually about one-fourth that ob- during waking hours. Respiration is increased after meals, particularly meal is large, owing, to some extent, to limitation of the excursions of aphragm as a result of gastric distention. Respiratory rate is little influ- by external temperature. It is, however, easily modified by the internal

temperature and is definitely increased by fever, in general bearing a relation to the height of the temperature (see Table 122). Respiration is increased by exercise, the degree of increase depending upon the duration and severity of the muscular effort. Variations in the rate of respiration are more readily induced in young, aged or asthenic persons than in strong adults. The character and the rate of respiration are easily modified by nervous and psychic factors.

These factors must be taken into account when estimating the rate of respiration. Many persons unconsciously change the rate and depth of breathing when they know they are under observation. Therefore, in order to obtain

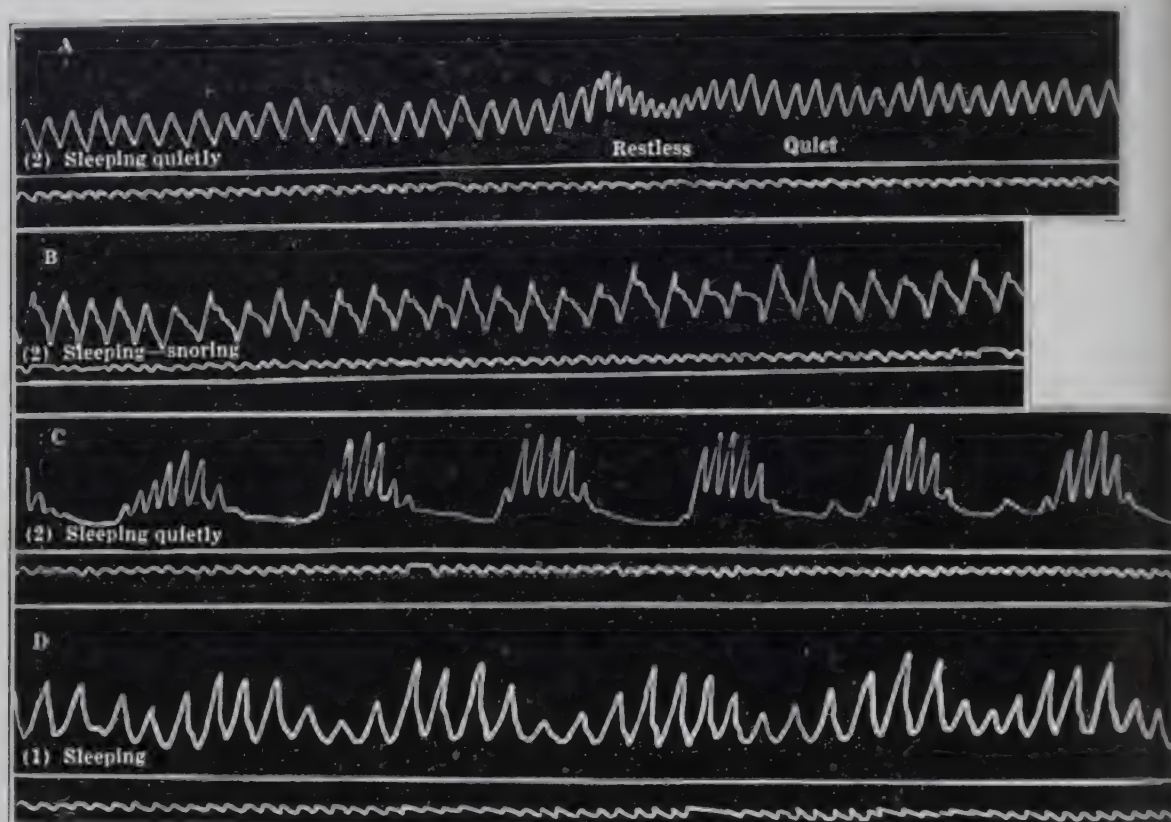


Fig. 55. Tracings of the principal types of breathing observed during sleep. A, Record of the regular type of respiration with fairly rapid rate, obtained from a male infant 12 days old and weighing  $8\frac{1}{2}$  pounds (3742.5 gm.); B, record of the slow type with prolonged cogwheel expiration, obtained from a male infant 5 weeks old and weighing 8 pounds (3628 gm.); C, record of the extremely periodic type, resembling Cheyne-Stokes respiration, obtained from a male infant 24 days old and weighing  $8\frac{1}{2}$  pounds (3855.5 gm.); D, record of the moderately periodic type, obtained from a female infant 4 weeks old and weighing 9 pounds (4082.3 gm.). (Deming, J., and Washburn, A. H.: *Am. J. Dis. Child.*, vol. 49.)

an accurate estimate, the respiratory rate should be counted for at least a full minute, better several minutes, unobtrusively and preferably without the subject knowing that his breathing is being observed.

**TYPES OF BREATHING.** In normal infants breathing may be irregular and bizarre. Rhythmic respiration is fully established at the end of the second year. The type of breathing in young children is diaphragmatic until the seventh year, when it becomes costal (see Fig. 55).

In men and children the respiratory act is accomplished chiefly by movements of the diaphragm and abdominal muscles; consequently greater excursions

noted in the lower thorax and abdomen (*abdominal* breathing). Women, on the other hand, make more use of their intercostal muscles when breathing. This movement is, therefore, more obvious in the upper thorax (*thoracic* breathing).

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## Chapter 25

### VITAL CAPACITY

ADULTS. Vital capacity of the lungs varies with the person's race, sex, age, weight, height, chest expansion, muscularity, occupation and physical training. It is usually measured by a simple spirometer of about 8 liters' capacity, three trials being allowed and the largest reading accepted.

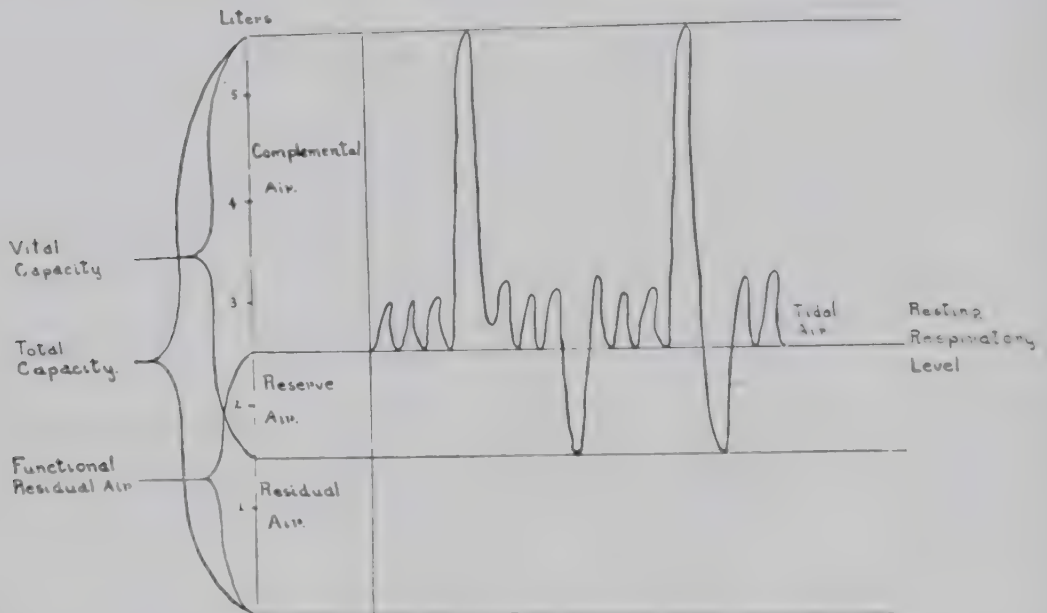


Fig. 56. The lung volume and its subdivisions. (Christie, R. V.: J. Clin. Investigation, vol. 2.

TABLE 125

#### VOLUME OF AIR BREATHED BY AVERAGE MAN

(Henderson and Haggard, 1943)<sup>5</sup>

	Liters per Minute at 20°C.
Rest in bed, fasting	6
Sitting	7
Standing	8
Walking 2 miles per hour	14
Walking 4 miles per hour	26
Slow run	43
Maximum exertion	65-100

There are fairly constant correlations between the vital capacity and other body measurements, such as standing height, sitting height, body surface area and chest circumference. Before a test can render its greatest service, reasonably accurate, normal standards must be developed for comparative purposes. The standards used when recording the vital capacity should always be stated.

Several theoretical norms have been developed and used as standards for comparison, such as the "standing height," "sitting height," "surface area," "circumference" and "body weight" standards (see Tables 132 to 137).

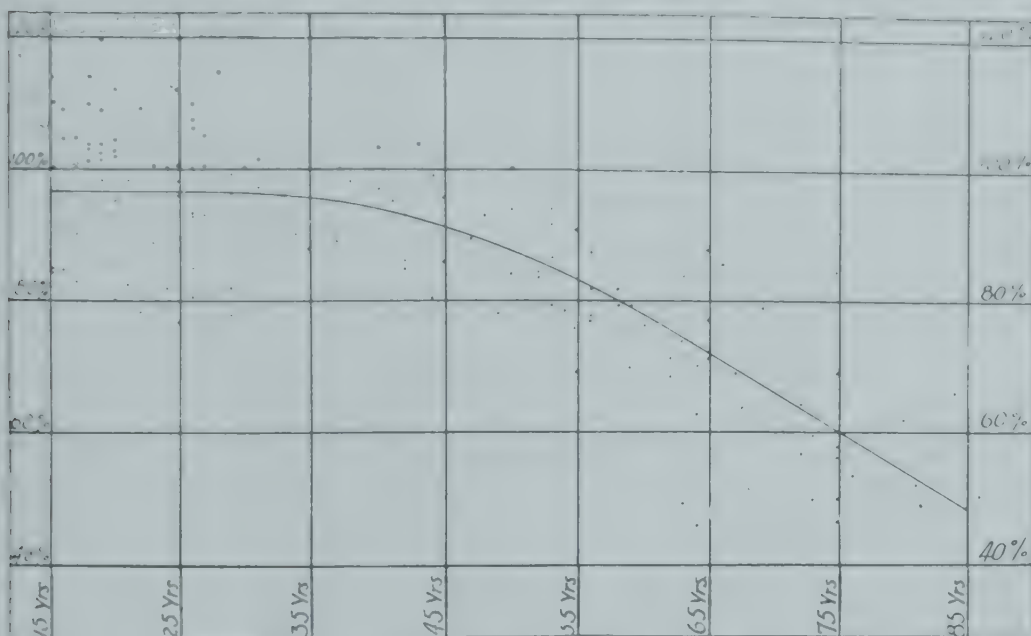


Fig. 57. Effects of age on vital capacity. (Bowen, B. D., and Platt, D. L.: Arch. Int. Med., vol. 31.)

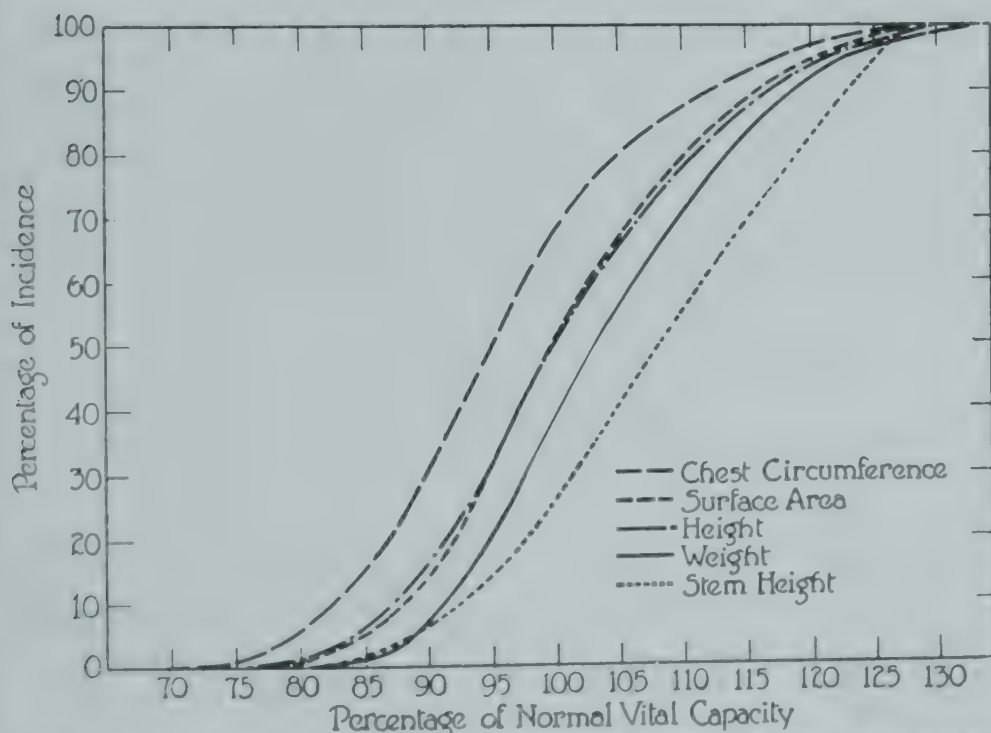


Fig. 58. Curves showing the results obtained in vital capacity work by various standards. Data for these curves were obtained from observations on 1641 normal male university students. Note the close relationship between the curves representing the surface area, the height, and the weight standards. (Shepard, W. B., and Myers, J. A.: Arch. Int. Med., vol. 35.)

Normal values may be reported in milliliters or by a number representing percentage of normal. The latter should indicate whether it has been correlated with surface area, height or weight standards (see Fig. 58, and Table 126).

RESPIRATORY SYSTEM

TABLE 126  
VITAL CAPACITY OF LUNGS  
(Peabody and Wentworth, 1917)<sup>12</sup>  
Normal Men

Group	Number Studied	Height	Normal Vital Capacity	Number within 10% of Normal	Highest Vital Capacity (ml.)	Lowest Vital Capacity (ml.)	Highest per Cent	Lowest per Cent	Number of Cases
I.....	14	6' —	5100	9	7180	5030	141	99	0
II.....	44	Over 5' 8½" to 6'	4800	41	5800	4300	121	90	0
III.....	38	5' 3" to 5' 8½"	4000	31	5080	3450	127	86	1

Normal Women

I.....	10	Over 5'6"	3275	5	4075	2800	124	86	2
II.....	13	Over 5'4" to 5'6"	3050	9	3425	2660	112	88	2
III.....	21	5'4" or less	2825	16	3820	2500	135	89	1

RACE DIFFERENCES. The vital capacity of the Negro race in both sexes and for all age groups is distinctly lower than that of the white race. When calculated from surface area, the difference is from 15 to 20 per cent lower in children and from 25 to 35 per cent in adults (see Tables 127, 128 and 130).<sup>13</sup>

When the vital capacity is calculated from stem length, the difference is not so great (10 to 15 per cent lower than the white), owing to the fact that Negroes have a shorter trunk length than white persons.

TABLE 127  
MEAN VITAL CAPACITY, WHITE AND NEGRO BOYS  
(Smillie and Augustine, 1926)<sup>15</sup>

Ages	White		Negro	
	Number of Cases	Mean V.C. (ml.)	Number of Cases	Mean V.C. (ml.)
6-7.....	39	1185	22	1089
8-9.....	62	1511	34	1167
10-11.....	50	1840	38	1597
12-13.....	41	2271	42	1931
14-15.....	38	2839	28	2331
16-17.....	22	3690	8	3030
Total	252		172	

TABLE 128

COMPARISON OF PERCENTAGE OF VITAL CAPACITY OF MALE WHITES AND NEGROES, CALCULATED FROM SURFACE AREA  
(From Myers)

10-Year Age Groups	White		Negro	
	Number of Cases	Mean V.C.	Number of Cases	Mean V.C.
.....	14	98.5	25	69.9
.....	16	99.8	31	69.7
.....	15	92.4	11	67.6
.....	12	92.6	17	66.6
Total .....	57		84	

TABLE 129

COMPARISON OF PERCENTAGE OF VITAL CAPACITY OF NORMAL ADULT WHITE AND NEGRO MALES, FROM 20 TO 45 YEARS OF AGE  
(Calculated from Myers, 1925)<sup>9</sup>

	Mean per Cent	
	White	Negro
Calculated from surface area .....	96.93	69.9
Calculated from standing height .....	98.5	72.6
Calculated from sitting height .....	103.2	86.3
	(42 cases)	(75 cases)

TABLE 130

PERCENTAGE OF VITAL CAPACITY OF UNIVERSITY OF THE PHILIPPINES STUDENTS COMPARED WITH THAT OF CHINESE AND OCCIDENTAL GROUPS  
(Nanagas and Santiago, 1927)<sup>11</sup>

Group	Vital Capacity (ml.)	Difference	
		ml.	Per Cent
University .....	4651	2389	105.6
Stanford Junior University .....	4646	2384	105.4
University .....	4315	2053	90.7
Students (nonuniversity) .....	3602	1340	59.2
Chinese .....	3180	918	40.5
Chinese .....	2518	256	11.3
University of the Philippines (713-564 males, females) .....	2262		

INFANTS AND CHILDREN. The normal range and factors influencing the capacity of school children are as follows:<sup>18</sup>

A normal standard of 1.93 liters per square meter of surface area, allow-

ing a plus or minus of 10 per cent deviation (giving a normal range of 1.74-2.12 liters), was established from a study of a representative group of 362 children six to sixteen years of age.

2. A normal standard of 15.5 ml. for each centimeter in height was also indicated as another method of regulating the vital capacity measurement.

3. An analysis of some of the factors expected to influence the vital capacity measurement revealed that:

- (a) Boys show a vital capacity 6 per cent greater than that of girls.
- (b) Extremes of age give values at the lower and higher limits of the normal range established.

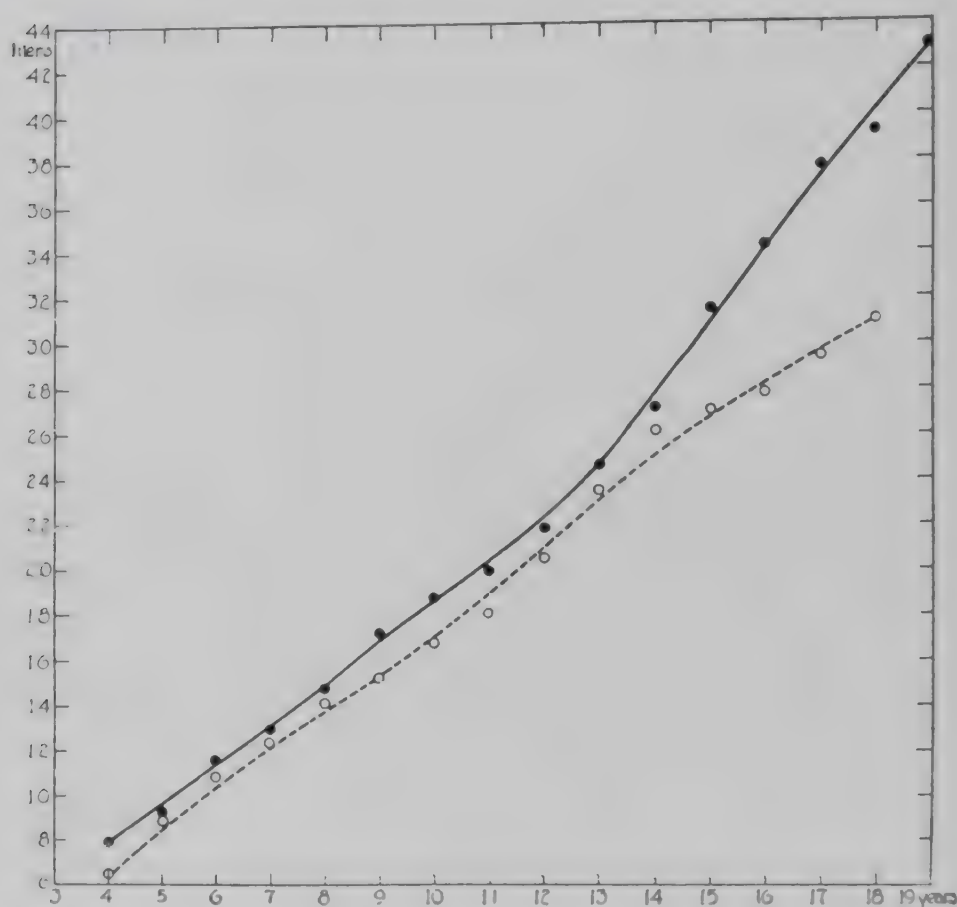


Fig. 59. Curves representing the average absolute increase in the vital capacity of the lungs, determined by graphic interpolation for boys between 4 and 19 years of age, inclusive, and girls between 4 and 18 years, inclusive. The actual averages at each age for the boys are represented by dots, and for the girls by circles. Vital capacity in liters is represented on the ordinate, and age in years on the abscissa. The solid line represents the boys; the broken line the girls. (Stewart, C. A., and Sheets, O. B.; *Am. J. Dis. Child.*, vol. 24.)

- (c) The Negro race shows a definitely lowered vital capacity (see Tables 128 and 129).
- (d) Poverty, environment and social status do not seem appreciably to influence the lung capacity.
- (e) Activity and athletics tend to increase the vital capacity.
- (f) Malnutrition and underweight for height do not lower the vital capacity.

- (g) Overweight for height reveals an apparent reduction of vital capacity per square meter of surface area.
- (h) Vital capacity is a fairly constant measurement.
- (i) A reduction of vital capacity measurement of 15 per cent or more from the average normal standard should signal the child out for further physical and roentgenographic examination.

TABLE 131

## VITAL CAPACITY OF NORMAL BOYS AND GIRLS

(Stewart and Sheets, 1922)<sup>16</sup>

## Normal Boys

No. of Cases	Standing Height (Cm.)	Average Vital Capacity (Cc.)	Minimum Vital Capacity (Cc.)	Maximum Vital Capacity (Cc.)	Probable Error of Random Sampling (Cc.)	Standard Deviation (Cc.)	Coefficient of Variation, per Cent
6	103.4	792	500	900			
20	106.8	927	600	1150			
62	112.2	1154	800	1600	15.6	182	15.8
112	116.9	1290	900	2200	12.3	194	15.0
98	121.8	1468	1050	2100	15.0	220	15.0
110	129.9	1715	1200	2300	15.8	246	14.3
87	133.4	1872	1400	2650	18.9	262	14.0
113	137.8	1991	1300	2800	17.1	270	13.6
114	142.4	2182	1300	3300	21.5	340	15.6
132	148.7	2458	1700	4000	25.2	430	17.5
177	154.8	2712	1400	4300	24.5	484	17.8
155	159.9	3145	1850	4400	29.8	551	17.5
67	167.2	3425	2100	4300	47.2	573	16.7
23	171.4	3776	2400	4500			
9	172.0	3922	2750	4400			
4	168.2	4300	4100	4500			

## Normal Girls

9	95.4	664	350	850			
26	106.4	888	600	1200			
62	111.5	1085	700	1600	14.0	163	15.0
81	114.4	1228	900	1800	13.6	181	14.7
76	121.0	1401	800	1950	15.4	199	13.5
73	127.0	1513	1000	2250	18.1	229	15.1
117	132.1	1672	900	2400	17.0	273	16.3
119	135.9	1799	1250	2550	14.9	241	13.4
135	144.0	2053	1400	2900	19.9	343	16.7
162	151.4	2349	1550	3600	21.7	409	17.5
192	156.6	2607	1900	3800	17.5	361	13.9
131	157.8	2702	1900	3700	24.3	413	15.3
29	160.1	2778	2050	3500			
7	162.6	2943	2250	3400			
1	162.0	3100					

TABLE 132  
 PERCENTAGE OF VITAL CAPACITY OF MEN CALCULATED FROM STANDING HEIGHT  
 Myers, 1925

Standing Height in Inches	Vital Capacity in Cubic Centimeters																				Standing Height in Cm.							
	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200		
57	19	22	25	28	30	33	36	39	41	44	47	50	52	55	58	61	64	66	69	72	75	77	80	83	86	88	144.8	
58	19	22	24	27	30	33	35	38	41	43	46	49	52	54	57	60	63	65	68	71	73	76	79	82	84	87	147.3	
59		21	24	27	29	32	35	37	40	43	45	48	51	53	56	59	61	64	67	69	72	75	77	80	83	85	149.8	
60		21	24	26	29	32	34	37	39	42	45	47	50	53	55	58	60	63	66	68	71	74	76	79	81	84	152.4	
61		21	23	26	28	31	34	36	39	41	44	47	49	52	54	57	59	62	65	67	70	72	75	78	80	83	154.9	
62		20	23	25	28	30	33	36	38	41	43	46	48	51	53	56	58	61	64	66	69	71	74	76	79	81	157.4	
63		20	23	25	28	30	33	35	38	40	43	45	48	50	53	55	58	60	63	65	68	70	73	75	78	80	160.0	
64		20	22	25	27	30	32	35	37	39	42	44	47	49	52	54	57	59	62	64	67	69	71	74	76	79	162.5	
65		22	22	24	27	29	32	34	36	39	41	44	46	48	51	53	56	58	61	63	66	68	70	73	75	78	165.1	
66		21	21	24	26	29	31	33	36	38	41	43	45	47	49	52	55	57	59	62	64	67	69	71	74	76	167.6	
67		21	21	24	26	28	31	33	35	38	40	42	45	47	49	52	54	56	59	61	63	66	68	71	73	75	170.2	
68		21	23	26	28	30	32	34	36	39	42	44	46	48	49	51	53	56	58	60	63	65	67	70	72	74	172.7	
69		21	23	25	27	30	32	34	37	39	41	43	45	47	48	50	52	55	57	59	62	64	66	68	71	73	175.3	
70		20	22	25	27	29	31	33	34	36	38	40	43	45	47	49	52	54	56	58	61	63	65	67	70	72	177.8	
71		20	22	24	26	28	30	31	33	35	38	40	42	44	47	49	51	53	55	58	60	62	64	67	69	71	180.4	
72		20	22	24	26	28	30	31	33	35	38	40	42	44	46	48	50	53	55	57	59	61	63	66	68	70	182.9	
73		19	21	22	24	26	28	30	32	35	37	39	41	43	45	47	49	50	52	54	56	58	60	63	65	67	69	185.4
74		19	21	22	24	26	28	30	32	34	36	38	40	43	45	47	49	51	53	55	57	59	62	64	66	68	187.9	
75		21	21	23	25	27	29	31	32	34	36	38	40	42	44	46	48	50	53	55	57	59	61	63	65	67	190.5	
76		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	53	55	57	59	61	63	65	67	193.0	
77		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	195.5
78		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	198.0
79		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	200.5
80		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	203.0
81		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	205.5
82		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	208.0
83		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	210.5
84		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	213.0
85		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	215.5
86		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	218.0
87		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	220.5
88		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	223.0
89		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	225.5
90		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	228.0
91		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	230.5
92		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	233.0
93		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	235.5
94		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	238.0
95		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	240.5
96		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	243.0
97		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	245.5
98		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	248.0
99		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	250.5
100		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	253.0
101		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	255.5
102		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	258.0
103		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	260.5
104		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	263.0
105		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	265.5
106		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	268.0
107		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	270.5
108		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	273.0
109		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	275.5
110		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	278.0
111		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	280.5
112		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	283.0
113		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	285.5
114		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	288.0
115		21	21	23	25	27	29	31	31	33	35	37	39	42	44	46	48	50	52	54	56	58	60	62	64	66	68	290

TABLE 132—Continued

Standing Feet	Vital Capacity in Cubic Centimeters																				Standing Height in Cent.							
	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200		5300	5400	5500	5600	5700	5800	
57	91	94	97	99	102	105	108	110	113	116	119	121															144.8	
58	90	92	95	98	100	103	106	109	111	114	117	120	122	123													147.3	
59	88	91	93	96	99	101	104	107	109	112	115	117	120	121	123												149.8	
60	87	89	92	95	97	100	102	105	108	110	113	115	118	121	123												152.4	
61	85	88	90	93	96	98	101	103	106	108	111	114	116	119	121	124											154.9	
62	84	86	89	91	94	97	99	102	104	107	109	112	114	117	119	122	123										157.4	
63	83	85	88	90	93	95	98	100	103	105	108	110	113	115	118	120	123										160.0	
64	81	84	86	89	91	94	96	99	101	103	106	108	111	113	116	119	121	123									162.5	
65	80	82	85	87	90	92	95	97	99	102	104	107	109	111	114	116	119	121	123								165.1	
66	79	81	83	86	88	91	93	95	98	100	102	105	107	110	112	114	117	119	121	124							167.6	
67	78	80	82	84	87	89	92	94	97	99	101	104	106	108	111	113	115	118	120	122	124						170.2	
68	76	79	81	83	86	88	90	93	95	97	100	102	104	107	109	111	114	116	118	120	123	125					172.7	
69	75	78	80	82	84	87	89	91	94	96	98	100	103	105	107	109	112	114	116	119	121	123	125				175.3	
70	74	76	78	80	82	84	86	88	90	92	94	97	99	101	103	106	108	110	112	115	117	119	121	124			177.8	
71	73	75	77	79	81	83	85	87	89	91	93	95	98	100	102	104	106	109	111	113	115	117	120	122	124		180.4	
72	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	107	109	111	114	116	118	120	122	124	182.9	
73	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	101	103	106	108	110	112	114	117	119	121	123	185.4	
74	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	117	119	121	188.0	
75	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105	107	109	111	113	115	117	120	123	190.5
76	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	99	101	103	105	107	109	111	113	116	118	120	122	193.0
																											194.0	
201.3	207.4	213.4	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	298.9	305.0	311.1	317.2	323.3	329.4	335.5	341.6	347.7	353.8			

Vital Capacity in Cubic Inches

Take the standing height of the patient, either in inches or centimeters. Locate in the vertical column, at the extreme left or extreme right of the table, the figures which correspond most closely to the standing height. Take the patient's vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column, at the top or bottom of the table, the figure which corresponds to the vital capacity. In the square where the two columns intersect will be found the percentage of the theoretical/normal vital capacity of the patient. If the height observed falls between the height figures on the table, one may easily calculate the percentage. Calculation may be made in a similar manner when the vital capacity observed falls between the vital capacity figures on the table.

TABLE 133  
 PERCENTAGE OF VITAL CAPACITY OF WOMEN CALCULATED FROM STANDING HEIGHT  
 (Myers, 1925)<sup>9</sup>

Standing Height in Inches	Vital Capacity in Cubic Centimeters																			Standing Height in Cm.	
	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400		2500
55	21	25	29	32	36	39	43	47	50	54	57	61	64	68	71	75	79	82	86	89	139.7
56	21	25	28	32	35	39	42	46	49	53	56	60	63	67	70	74	77	81	84	88	142.2
57	21	24	28	31	35	38	41	45	48	52	55	59	62	66	69	72	76	79	83	86	144.8
58	20	24	27	31	34	38	41	44	47	51	54	58	61	64	68	71	75	78	81	85	147.3
59	20	23	27	30	33	37	40	43	47	50	53	57	60	63	67	70	73	77	80	83	149.8
60	20	23	26	30	33	36	39	43	46	49	52	56	59	62	66	69	72	75	79	82	152.4
61	22	23	26	29	32	36	39	42	45	48	52	55	58	61	65	68	71	74	77	81	154.9
62	22	22	25	29	32	35	38	41	44	48	51	54	57	60	63	67	70	73	76	79	157.4
63	22	22	25	28	31	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	160.0
64	22	22	25	28	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73	76	162.5
65	21	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	165.1
66	21	21	24	27	29	32	35	38	41	44	47	50	53	56	59	62	65	68	71	74	167.6
67	21	21	24	27	29	32	35	38	41	44	46	49	52	55	58	61	64	67	69	72	170.2
68	20	20	23	26	29	31	34	37	40	43	46	49	51	54	57	60	63	66	68	71	172.7
69	20	20	22	25	28	31	34	37	39	42	45	48	51	53	56	59	62	65	67	70	175.3
70	20	22	22	25	28	31	33	36	39	42	44	47	50	53	55	58	61	64	66	69	177.8
71	21	22	22	25	27	30	33	35	38	41	44	47	49	52	54	57	60	63	65	68	180.4
72	21	22	22	24	27	30	33	35	38	41	44	47	49	52	54	57	59	62	65	67	182.9
73	21	21	21	24	27	29	32	35	37	40	43	46	49	51	54	57	59	62	65	67	185.4
74	21	21	21	24	27	29	32	35	37	40	43	45	48	51	53	56	59	61	64	67	188.0
36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5		
Vital Capacity in Cubic Inches																					

Vital Capacity in Cubic Inches

TABLE 133 Continued

Standing Height in Inches	Vital Capacity in Cubic Centimeters																	Standing Height in Centimeters		
	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200		4300	4400
55	93	96	100	103	107	111	114	118	121	123										139.7
56	91	95	98	102	105	109	112	116	119	123										142.2
57	90	93	97	100	103	107	110	114	117	121										144.8
58	88	91	95	98	102	105	108	112	115	118	122									147.3
59	87	90	93	97	100	103	107	110	113	117	120	123								149.8
60	85	88	92	95	98	102	105	108	112	115	118	121	122							152.4
61	84	87	90	94	97	100	103	106	110	113	116	119	121	122						154.9
62	83	86	89	92	95	98	102	105	108	111	114	118	121	122						157.4
63	81	84	88	91	94	97	100	103	106	109	112	115	118	120	121					160.0
64	80	83	86	89	92	95	98	101	105	108	111	114	117	120	121	122				162.5
65	79	82	85	88	91	94	97	100	103	106	109	112	115	118	119	120	122			165.1
66	78	81	84	87	90	93	96	98	101	104	107	110	113	116	118	120	122	123		167.6
67	77	79	82	85	88	91	94	97	100	103	106	109	112	115	118	119	121	123		170.2
68	75	78	81	84	87	90	93	96	98	101	104	107	110	113	116	119	121	123		172.7
69	74	77	80	83	85	88	91	94	97	100	102	105	108	111	114	117	120	121	123	175.3
70	73	76	79	82	84	87	90	93	96	98	101	104	107	110	112	115	118	119	121	177.8
71	72	75	78	80	83	86	89	91	94	97	100	102	105	108	111	114	116	119	122	180.4
72	71	74	77	79	82	85	88	90	93	96	98	101	104	107	109	112	115	118	120	182.9
73	70	73	76	78	81	84	86	89	92	94	97	100	102	105	108	111	113	116	119	185.4
74	69	72	75	77	80	83	85	88	90	93	96	99	101	104	106	109	112	114	117	188.0
	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5

Vital Capacity in Cubic Inches

Take the standing height of the patient, either in inches or centimeters. Locate in the vertical column, at the extreme left or extreme right of the table, the figure which corresponds most closely to the standing height. Take the patient's vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom of the table the figure which corresponds most closely to the vital capacity observed. Now use the table in precisely the same manner as Table 132 is used.



TABLE 134—Continued

Surface Area in Sq. Meters		Vital Capacity in Cubic Centimeters																											
		3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300	5400	5500	5600	5700	5800	5900	
0.7		120	123																										
0.75		115	118	122																									
0.8		110	113	117	120																								
0.85		106	109	112	115	118	122																						
0.9		101	105	108	111	114	117	120																					
0.95		98	101	104	107	110	113	115	118	121																			
1.0		94	97	100	103	106	109	111	114	117	120																		
1.05		91	94	97	99	102	105	108	110	113	116	119																	
1.1		88	91	93	96	99	101	104	107	109	112	115	118																
1.15		85	88	90	93	96	98	101	103	106	108	111	114	116	119	121													
1.55		83	85	88	90	93	95	98	100	103	105	108	110	113	115	118	120												
1.65		80	82	85	87	90	92	94	97	99	102	104	107	109	111	114	116	119	121										
1.7		78	80	82	85	87	89	92	94	96	99	101	103	106	108	110	113	115	117	120									
1.75		75	78	80	82	85	87	89	91	94	96	98	101	103	105	107	110	112	114	117	119	121							
1.8		73	76	78	80	82	85	87	89	91	93	96	98	100	102	104	107	109	111	113	115	118	120						
1.85		71	74	76	78	80	82	84	87	89	91	93	95	97	99	102	104	106	108	110	112	114	117	119	121				
1.9		69	72	74	76	78	80	82	84	86	88	91	93	95	97	99	101	103	105	107	109	112	114	117	119	121			
1.95		68	70	72	74	76	78	80	82	84	86	88	90	92	94	97	98	99	100	103	105	107	109	111	113	115	117	119	
2.0		66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	
2.05		64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	
2.1		63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105	107	109	111	113	115	
2.15		61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105	107	109	111	113	
2.2		60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	
2.25		59	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	
2.3		57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105	107	109	
2.35		56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	
2.4		55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105	107	
2.45		54	56	58	60	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	
2.5		53	55	57	59	61	63	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	101	103	105	

Vital Capacity in Cubic Inches

Locate in the vertical column at the extreme left the figure which corresponds most closely with the surface area of the patient. Take the patient's vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom of the table the figure which corresponds most closely to the vital capacity observed. Now use the table in precisely the same manner as Table 132 is used.

TABLE 135  
 PERCENTAGE OF VITAL CAPACITY OF WOMEN CALCULATED FROM SURFACE AREA  
 (Myers, 1925)<sup>9</sup>

Surface Area in Sq. Meters	Vital Capacity in Cubic Centimeters																					
	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500
0.5	42	52	63	73	84	94	104	115	125	123	122	120	119	127	125	124	123	122	121	126		
0.55	38	47	57	66	76	85	95	104	114	113	112	112	111	118	117	116	116	115	115	120	125	
0.6	35	43	52	61	69	78	87	95	104	104	104	104	104	111	110	109	109	109	109	114	119	124
0.65	32	40	48	56	64	72	80	88	96	104	104	104	104	104	110	109	109	109	109	114	119	124
0.7	30	37	45	52	60	67	75	82	90	97	104	104	104	104	110	109	109	109	109	114	119	124
0.75	28	35	42	49	56	63	69	76	83	85	91	98	104	104	110	109	109	109	109	114	119	124
0.8	26	33	39	46	52	59	65	72	78	80	86	92	98	104	110	109	109	109	109	114	119	124
0.85	25	31	37	43	49	55	61	67	74	73	81	87	93	98	104	109	109	109	109	114	119	124
0.9	23	29	35	40	46	52	58	64	69	70	77	82	88	93	99	104	104	104	104	109	113	118
0.95	22	27	33	38	44	49	55	60	66	67	73	78	83	89	94	99	104	104	104	109	113	118
1.0	21	26	31	37	42	47	52	57	63	64	69	74	79	84	89	94	99	104	104	109	113	118
1.05	20	25	30	35	40	45	50	55	60	62	66	71	76	80	85	90	95	99	104	109	113	118
1.1	21	26	31	37	42	47	52	57	63	63	68	73	78	83	88	93	98	103	108	113	118	123
1.15	20	25	30	35	40	45	50	55	60	61	65	69	74	77	81	86	91	95	99	104	109	113
1.2	22	27	32	37	42	47	52	57	62	62	67	72	77	82	87	92	97	102	107	112	117	122
1.25	21	26	31	36	41	46	51	56	61	61	66	71	76	81	86	91	96	101	106	111	116	121
1.3	23	28	33	38	43	48	53	58	63	63	68	73	78	83	88	93	98	103	108	113	118	123
1.35	22	27	32	37	42	47	52	57	62	62	67	72	77	82	87	92	97	102	107	112	117	122
1.4	26	31	36	41	46	51	56	61	66	66	71	76	81	86	91	96	101	106	111	116	121	126
1.45	25	30	35	40	45	50	55	60	65	65	70	75	80	85	90	95	100	105	110	115	120	125
1.5	24	29	34	39	44	49	54	59	64	64	69	74	79	84	89	94	99	104	109	114	119	124
1.55	23	28	33	38	43	48	53	58	63	63	68	73	78	83	88	93	98	103	108	113	118	123
1.6	22	27	32	37	42	47	52	57	62	62	67	72	77	82	87	92	97	102	107	112	117	122
1.65	21	26	31	36	41	46	51	56	61	61	66	71	76	81	86	91	96	101	106	111	116	121
1.7	21	26	31	36	41	46	51	56	61	61	66	71	76	81	86	91	96	101	106	111	116	121
1.75	21	26	31	36	41	46	51	56	61	61	66	71	76	81	86	91	96	101	106	111	116	121
1.8	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
1.85	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
1.9	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
1.95	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.0	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.05	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.1	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.15	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.2	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.25	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.3	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.35	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
2.4	20	25	30	35	40	45	50	55	60	60	65	70	75	80	85	90	95	100	105	110	115	120
	21.4	26.3	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5

Vital Capacity in Cubic Inches

Surface Area  
in Sq. Meters

Vital Capacity in Cubic Centimeters

	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600
0.45																					
0.50																					
0.6																					
0.65																					
0.7																					
0.75																					
0.8																					
0.85																					
0.9																					
0.95																					
1.0																					
1.05																					
1.1																					
1.15																					
1.2																					
1.25																					
1.3																					
1.35																					
1.4																					
1.45																					
1.5																					
1.55																					
1.6																					
1.65																					
1.7																					
1.75																					
1.8																					
1.85																					
1.9																					
1.95																					
2.0																					
2.05																					
2.1																					
2.15																					
2.2																					
2.25																					
2.3																					
2.35																					
2.4																					

Vital Capacity in Cubic Inches

Locate in the vertical column at the extreme left the figure which corresponds most closely with the surface area of the patient. Take the patient's vital capacity in cubic centimeters or cubic inches located in the horizontal column at the top or bottom of the table the figure which corresponds most closely to the vital capacity observed. Now use the table in precisely the same manner as Table 132 is used.

TABLE 136  
 PERCENTAGE OF VITAL CAPACITY OF MEN CALCULATED FROM BODY WEIGHT  
 (Myers, 1925)<sup>a</sup>

Body Weight in Pounds		Vital Capacity in Cubic Centimeters																				Body Weight in Kg.									
		600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500			2600	2700	2800	2900	3000	3100	3200	3300
90	20	23	26	30	33	36	40	43	46	50	53	56	59	63	66	69	73	76	79	82	86	89	92	96	99	102	105	109	112	40.8	
95	19	22	25	29	32	35	38	41	45	48	51	54	57	60	64	67	70	73	76	79	83	86	89	92	95	99	102	105	108	43.1	
100	18	21	24	28	31	34	37	40	43	46	49	52	55	58	61	64	67	70	73	76	80	83	86	89	92	95	98	101	104	45.4	
105	18	21	24	27	30	33	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	80	83	86	89	92	95	98	101	47.6	
110		20	23	26	29	31	34	37	40	43	46	49	51	54	57	60	63	66	69	71	74	77	80	83	86	89	91	94	97	49.9	
115		19	22	25	28	30	33	36	39	42	44	47	50	53	56	58	61	64	67	69	72	75	78	81	83	86	89	92	94	52.2	
120		19	21	24	27	30	32	35	38	40	43	46	48	51	54	56	59	62	64	67	70	73	75	78	81	83	86	89	91	54.4	
125			20	23	26	29	31	34	37	39	42	44	47	50	52	55	57	60	63	65	68	70	73	76	78	81	83	86	89	56.7	
130			20	23	26	28	30	33	36	38	41	43	46	48	51	53	56	58	61	63	66	68	71	74	76	78	81	84	86	59.0	
135			20	22	25	27	30	32	35	37	39	42	44	47	49	53	54	57	59	62	64	67	69	72	74	76	79	81	84	61.3	
140			19	22	24	26	29	31	34	36	38	41	43	46	48	50	53	55	58	60	62	65	67	70	72	74	77	79	82	63.5	
145			19	21	23	26	28	30	33	35	37	40	42	44	47	48	52	54	56	59	61	63	66	68	70	73	75	77	80	65.7	
150			20	22	25	27	30	32	34	37	39	41	43	46	48	50	53	55	57	59	62	64	66	69	71	73	75	77	78	68.0	
155			20	22	25	27	29	31	34	36	38	40	42	45	47	49	51	54	56	58	60	63	65	67	69	72	74	76	77	79	70.4
160				21	24	26	28	30	32	34	36	38	41	43	45	47	49	51	53	55	57	59	61	63	66	68	70	72	74	74	72.5
165					21	24	26	28	30	32	34	36	38	41	43	45	47	49	51	53	56	58	60	62	64	66	68	71	73	74	74.8
170					21	23	25	27	29	31	33	35	37	39	42	44	46	48	50	52	54	56	59	61	63	65	67	69	71	71	77.1
175					20	22	24	26	28	30	32	34	36	38	41	43	45	47	49	51	53	55	57	60	61	64	66	68	70	70	79.4
180					20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	81.6
185					20	22	24	26	28	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	83.9	
190					19	21	23	25	27	29	31	33	35	37	39	41	42	44	46	48	50	52	54	56	58	60	62	64	67	86.2	
195					19	21	23	25	26	28	30	32	34	36	38	40	42	44	45	47	49	51	53	55	57	59	61	62	64	64	88.5
200					19	20	22	24	26	28	30	32	33	35	37	39	43	43	45	46	48	50	52	54	56	57	59	61	62	64	90.7
205						20	22	24	26	27	29	31	33	35	37	38	40	42	44	45	47	48	50	52	54	56	57	59	60	62	93.0
210						20	22	23	25	27	29	31	32	34	36	38	39	41	43	45	47	48	50	52	54	56	58	59	61	61	95.2
215						19	21	23	25	26	28	30	32	33	35	37	39	41	43	44	46	48	49	51	53	55	56	58	60	60	97.5
220						19	21	22	24	26	28	29	31	33	35	36	38	40	42	43	45	47	49	51	52	54	56	57	59	59	99.8
225						19	20	22	24	26	27	29	31	32	34	36	38	39	41	43	44	46	48	49	51	52	54	55	56	58	102.0
	36.6	42.7	48.8	54.9	61.0	67.1	73.2	79.3	85.4	91.5	97.6	103.7	109.8	115.9	122.0	128.1	134.2	140.3	146.4	152.5	158.6	164.7	170.8	176.9	183.0	189.1	195.2	201.3	207.4		

Vital Capacity in Cubic Inches

Vital Capacity in Cubic Inches

TABLE 136—Continued

R. W. in Pounds		Vital Capacity in Cubic Centimeters																			Body Weight in Kg.									
		3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700	4800	4900	5000	5100	5200	5300		5400	5500	5600	5700	5800	5900	6000	6100	6200
90	115	119	122																											40.8
95	111	114	118	121																										43.1
100	107	110	113	116	119	122																								45.4
105	104	107	109	112	115	118	121																							47.6
110	100	103	106	109	111	114	117	120																						49.9
115	97	100	103	105	108	111	114	117	119	122																				52.2
120	94	97	99	102	105	107	110	113	115	118	121																			54.4
125	91	94	97	99	102	104	107	110	112	115	118	121																		56.7
130	89	91	94	96	99	101	104	106	109	112	114	117	119	122																59.0
135	86	89	91	94	96	99	101	103	106	109	111	113	116	118	121															61.3
140	84	86	89	91	94	96	98	101	103	105	107	109	111	113	115	118	121													63.5
145	82	84	87	89	91	94	96	98	100	102	104	106	108	110	112	114	117	119	122											65.7
150	80	82	85	87	89	91	94	96	98	100	103	105	107	109	111	113	115	118	121											68.0
155	78	80	83	85	87	89	92	94	96	98	101	103	105	107	109	111	113	115	118	121										70.4
160	76	79	81	83	85	87	90	92	94	96	98	100	103	105	107	109	111	113	115	118	120									72.6
165	75	77	79	81	83	86	88	90	92	94	96	98	100	102	104	106	108	110	113	115	118	120	117	119	121					74.8
170	73	75	77	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	113	115	118	120	116	118	121				77.1
175	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	113	115	118	120	117	119	121			79.4
180	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120				81.6
185	69	71	73	75	77	79	81	83	85	87	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120			83.9
190	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	100	102	104	106	108	110	112	114	116	118	120			86.2
195	66	68	70	72	74	76	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120		88.5
200	65	67	69	71	73	75	77	79	81	83	85	87	89	91	93	95	97	99	100	102	104	106	108	110	112	114	116	118	120	90.7
205	64	66	68	70	72	74	76	78	80	82	84	86	88	90	91	93	95	97	99	100	102	104	106	108	110	112	114	116	118	93.0
210	63	65	67	69	71	73	75	77	79	81	83	85	87	89	90	92	93	95	97	99	101	102	104	106	108	110	112	114	116	95.2
215	62	64	66	68	70	72	74	76	78	80	82	84	86	88	89	91	92	93	95	97	99	100	102	104	106	108	110	112	114	97.5
220	61	63	65	67	69	71	73	75	77	79	81	83	85	87	88	90	92	93	95	97	99	100	102	104	106	108	110	112	114	99.8
225	60	61	63	65	67	68	70	72	73	75	77	79	80	82	83	85	87	89	90	92	94	96	97	99	101	102	104	106	108	102.0
		213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8	298.9	305.0	311.1	317.2	323.3	329.4	335.5	341.6	347.7	353.8	359.9	366.0	372.1	378.3	
		Vital Capacity in Cubic Inches																												

Vital Capacity in Cubic Inches

Take the actual weight without clothing of the patient, in either pounds or kilograms. If the patient is obese or emaciated, use the theoretical normal weight. Locate in the vertical column at the extreme left or extreme right the figure which corresponds most closely to the weight. Now take the vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom the figures corresponding most closely to the vital capacity observed. Now use the table in precisely the same manner as Table 132 is used.

TABLE 137  
PERCENTAGE OF VITAL CAPACITY OF WOMEN CALCULATED FROM BODY WEIGHT  
(Myers, 1925)<sup>9</sup>

Body Weight in Pounds	Vital Capacity in Cubic Centimeters																	Body Weight in K.g.					
	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200		2300	2400	2500	2600	2700
80	26	31	35	39	44	48	53	57	61	66	70	74	79	83	88	92	97	101	105	110	114	118	36.3
85	25	30	34	38	42	46	52	55	59	63	67	72	76	80	84	88	93	97	101	105	110	114	38.5
90	24	28	32	36	41	45	49	53	57	61	65	69	73	77	81	85	89	93	97	101	105	109	40.8
95	23	27	31	35	39	43	47	51	55	59	63	67	70	74	78	82	86	90	94	98	102	106	43.1
100	23	26	30	34	38	42	45	49	53	57	60	64	68	72	75	79	83	87	91	94	98	102	45.4
105	22	25	29	33	36	40	44	47	51	55	58	62	66	69	73	76	80	84	87	91	95	98	47.6
110	21	25	27	32	35	39	42	46	49	53	57	60	63	67	70	74	77	81	84	88	92	95	49.9
115	20	23	27	31	34	38	41	44	47	51	55	58	61	65	68	72	75	78	82	85	89	92	52.2
120	20	23	26	30	33	36	40	43	46	50	53	56	60	63	66	70	73	76	79	83	86	89	54.4
125	19	22	25	29	32	35	39	42	45	48	51	55	58	61	64	68	71	74	77	80	84	87	56.7
130	19	22	25	28	31	34	37	41	44	47	50	53	56	58	62	66	69	72	75	78	81	84	59.0
135	19	21	24	27	30	33	36	39	42	46	49	52	55	58	61	64	67	70	73	76	79	82	61.3
140	19	21	24	27	30	33	35	38	41	44	47	50	53	56	59	62	65	68	71	74	77	80	63.5
145	19	20	23	26	29	32	35	38	40	43	46	49	52	55	58	61	64	66	69	72	75	78	65.7
150	19	20	22	25	28	31	34	37	39	42	45	48	51	53	56	58	62	65	68	70	73	76	68.0
155	19	19	22	25	27	30	33	36	39	41	44	47	50	52	55	58	61	63	66	69	72	74	70.4
160	19	19	21	24	26	29	32	35	38	40	43	46	48	51	54	57	59	62	65	67	70	73	72.5
165	19	19	21	24	26	29	32	34	37	40	42	45	47	50	53	55	58	61	63	66	68	71	74.8
170	19	19	21	23	26	28	31	34	36	39	41	44	46	49	52	54	57	59	62	64	67	70	77.1
175	19	19	20	23	25	28	30	33	35	38	40	43	46	48	51	53	56	58	61	63	66	68	79.4
180	19	19	20	22	25	27	30	32	35	37	40	42	44	47	49	52	54	57	59	62	64	67	81.6
185	19	19	19	22	24	27	29	31	34	36	39	41	44	45	49	51	53	56	58	61	63	65	83.9
190	19	19	19	21	24	26	29	31	33	36	38	40	43	45	48	50	52	55	57	59	62	64	86.2
195	19	19	19	21	23	26	28	30	33	35	37	40	42	44	47	49	51	54	56	58	61	63	88.4
200	19	19	19	20	23	25	27	30	32	34	37	39	41	43	46	48	50	53	55	57	60	62	90.7
306	127	148	169	190	211	232	253	273	293	314	335	356	377	398	419	440	461	482	503	524	545	566	164.7

Vital Capacity in Cubic Inches

Vital Capacity in Cubic Inches

TABLE 137—Continued

Body Weight in Pounds	Vital Capacity in Cubic Centimeters																				Body Weight in Kg.	
	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500	4600	4700		4800
80	123																					36.3
85	118	122																				38.5
90	114	118	122																			40.8
95	110	113	117	121																		43.1
100	106	109	113	117	121																	45.4
105	102	106	109	113	116	120																47.6
110	99	102	106	109	112	116	119															49.9
115	96	99	102	106	109	113	116	119	119													52.2
120	93	96	99	103	106	109	112	115	116	119												54.4
125	90	93	97	100	103	106	109	112	115	118	119											56.7
130	87	91	94	97	100	103	106	109	112	115	118	121										59.0
135	85	88	91	94	97	100	103	106	109	112	115	118	121									61.3
140	83	86	89	92	95	98	101	103	106	109	112	115	118	121								63.5
145	81	84	87	90	92	95	98	101	104	107	110	113	115	118	121							65.7
150	79	82	84	87	90	93	96	99	101	104	107	110	112	115	118	121						68.0
155	77	80	83	85	88	91	94	97	99	102	105	107	110	113	115	118	121					70.4
160	75	78	81	83	86	89	91	94	97	99	102	105	108	110	113	115	118	120				72.5
165	74	76	79	82	84	87	90	92	95	97	100	103	105	108	110	113	116	118	121			74.8
170	72	75	77	80	82	85	88	90	93	95	98	100	103	106	108	111	113	116	119	122		77.1
175	71	73	76	78	81	83	86	88	91	94	96	99	101	103	106	109	111	114	117	120		79.4
180	69	72	74	77	79	82	84	87	89	91	94	96	99	101	104	105	109	111	114	117	120	81.6
185	68	70	73	75	78	80	82	85	87	90	92	94	97	99	102	104	107	109	111	114	117	83.9
190	67	69	71	74	76	79	81	83	86	88	91	93	95	98	100	102	105	107	109	112	114	86.2
195	65	68	70	72	75	77	79	82	84	86	89	91	93	96	98	100	102	105	107	110	112	88.4
200	64	66	69	71	73	76	78	80	82	85	87	89	92	94	96	98	101	103	105	107	110	90.7
170.8	176.9	183.0	189.1	195.2	201.3	207.4	213.5	219.6	225.7	231.8	237.9	244.0	250.1	256.2	262.3	268.4	274.5	280.6	286.7	292.8		

Vital Capacity in Cubic Inches

Take the actual weight, without clothing, of the patient, in either pounds or kilograms. If the patient is obese or emaciated, use the theoretical normal weight. Locate in the vertical column at the extreme left or extreme right the figure which corresponds most closely to the weight. Now take the vital capacity in cubic centimeters or cubic inches. Locate in the horizontal column at the top or bottom the figures corresponding most closely to the vital capacity observed. Now use the table in precisely the same manner as Table 132 is used.

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Section V

DIGESTIVE SYSTEM

(Normal Values in Gastroenterology)



Chapter 26

THE ESOPHAGUS AND STOMACH

THE ESOPHAGUS

FIGURE 60 shows the average length of the esophagus to the level of its principal anatomic constrictions at various ages. There is also a physiologic narrowing just below the constriction of the cricopharyngeus. This physiologic constriction is the common site of lodgment of esophageal foreign bodies. It is noteworthy that at this point the concavity of the upper dorsal spine joins the convexity of the cervical spine and that just below this point the esophagus enters the thoracic cage.

The esophagus being a muscular tube, the lumen is variable in size. Table 38 gives the maximum diameter of the various constrictions.

TABLE 138  
DIAMETER OF THE ESOPHAGUS AT THE LEVEL OF THE ESOPHAGEAL CONSTRICTIONS  
(Jackson and Jackson, 1927)<sup>15</sup>

Constriction	Diameter	Level
Cricopharyngeus . . . . .	23 mm. Transverse	6th cervical vertebra
	17 mm. Anteroposterior	
Aortic . . . . .	24 mm. Transverse	4th thoracic vertebra
	19 mm. Anteroposterior	
Left bronchus . . . . .	23 mm. Transverse	5th thoracic vertebra
	17 mm. Anteroposterior	
Diaphragmatic . . . . .	23 mm. Transverse	10th thoracic vertebra
	23 mm. Anteroposterior	

THE STOMACH

The stomach is located in the upper left abdomen; it occupies the left hypochondrium and epigastric regions, and may be divided into three parts: *pars cardiaca*, *pars media* and *pars pylorica* (Fig. 61).

SIZE. The normal stomach varies somewhat in size in different subjects. When filled, its longitudinal measurement is from 10 to 12 inches, and its greatest transverse diameter between the curvatures is about 5 inches.

CAPACITY. The capacity in average adults is 1000 to 1200 ml.

SHAPE. The form or shape varies widely in different persons (Fig. 62).

The stomach of infants does not tend to assume definite types. It may appear "pear-shaped," "retort-shaped," "tobacco pouch-shaped," to intermediate shapes which cannot be classified (Fig. 63).<sup>2</sup>

GASTRIC CONTENTS AND SECRETIONS

Fractional gastric analysis is the principal procedure used for studying the contents and secretory function of the stomach. Most of the popular technics

DIGESTIVE SYSTEM

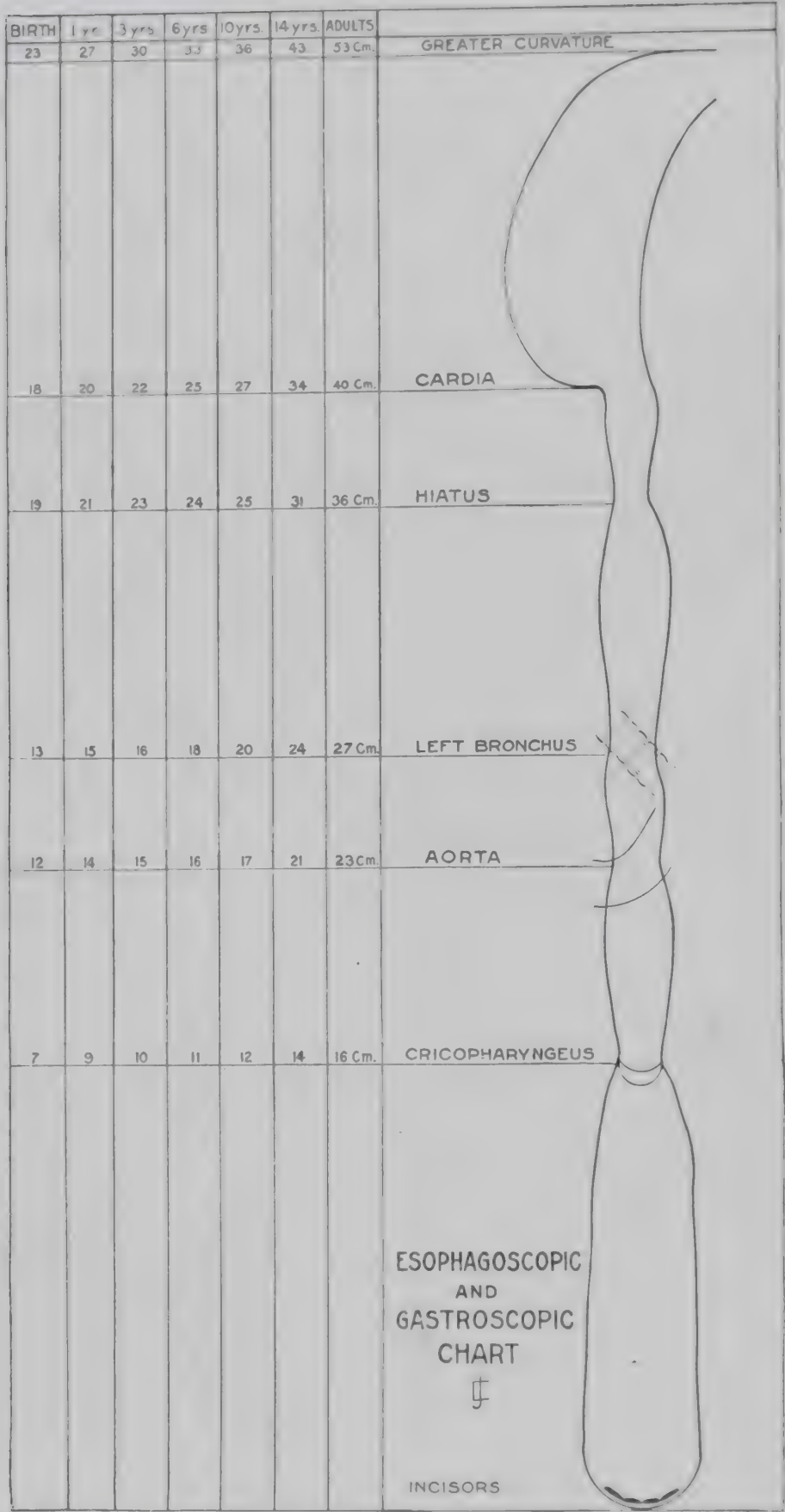
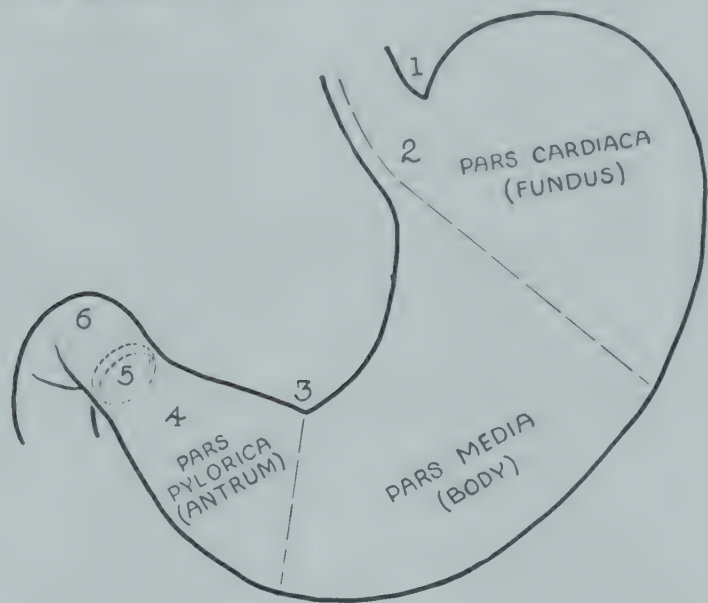


Fig. 60. Approximate distances of the esophageal narrowings from the upper incisor teeth, at various ages, arranged for convenient reference during esophagoscopy in the dorsally recumbent patient. [Jackson, C., and Jackson, C. L.: Bronchoscopy and Esophagoscopy.]

is patterned after that described by Rehfuess.<sup>22</sup> The fasting residuum is first studied, and then the secretion obtained after giving a test meal.

**COLOR.** The color of the normal fasting residuum\* is usually pearl-gray. When bile has been regurgitated from the duodenum, the gastric contents may have a yellow or even greenish tint.



- 1 *Incisura Cardiaca*
- 2 *Cardia*
- 3 *Incisura Angularis*
- 4 *Pyloric Canal*
- 5 *Pylorus*
- 6 *Duodenal Cap*

Fig. 61. Anatomic divisions of the stomach. (Bockus, H. L.: Gastro-Enterology, vol. 1.)

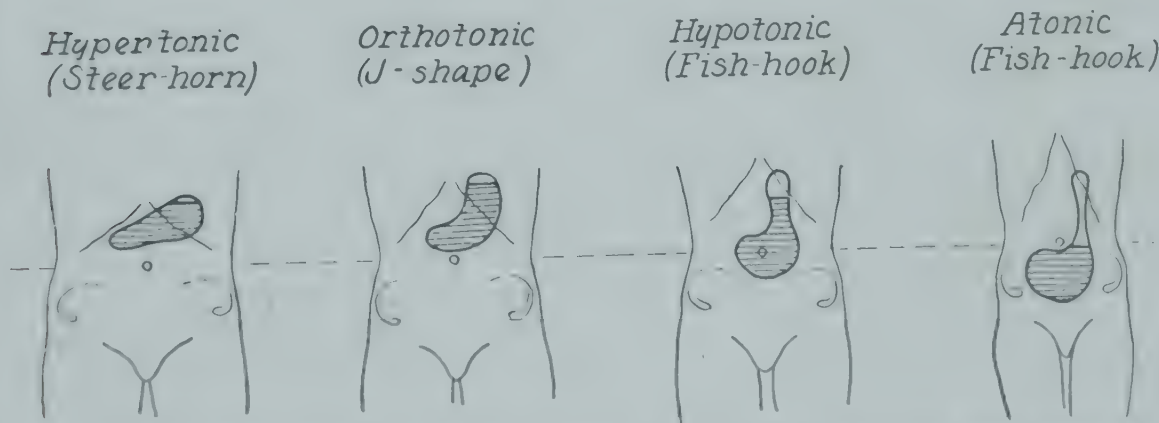


Fig. 62. Schlesinger's classification of gastric tonus. (Bockus, H. L.: Gastro-Enterology, vol. 1.)

**VOLUME.** Wolman<sup>23</sup> found the volume of gastric residuum in fifty-nine children to range from 0.4 to 80 ml., with a mean of 8.8 ml. and a standard deviation of 8.2; 83 per cent measured between 0.1 and 10 ml. in volume. In one case no fluid was obtained. The one case having 80 ml. subsequently exhib-

\* A fasting stomach is one which has not received food for a period of at least eight hours.

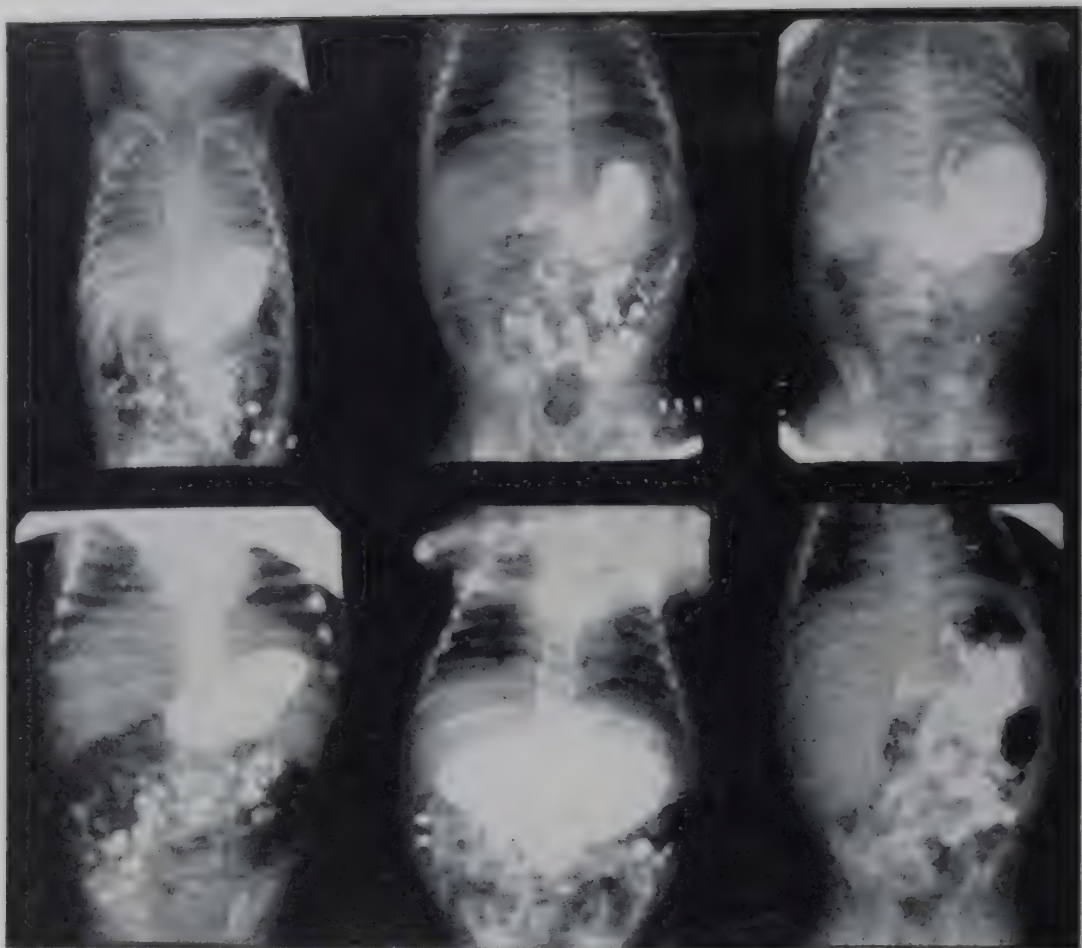


Fig. 63. Roentgenograms of stomachs of 6 infants 3 weeks to 4 months old, showing different sizes and shapes. (Bouslog, T. S., and others: J. Pediat., vol. 6.)

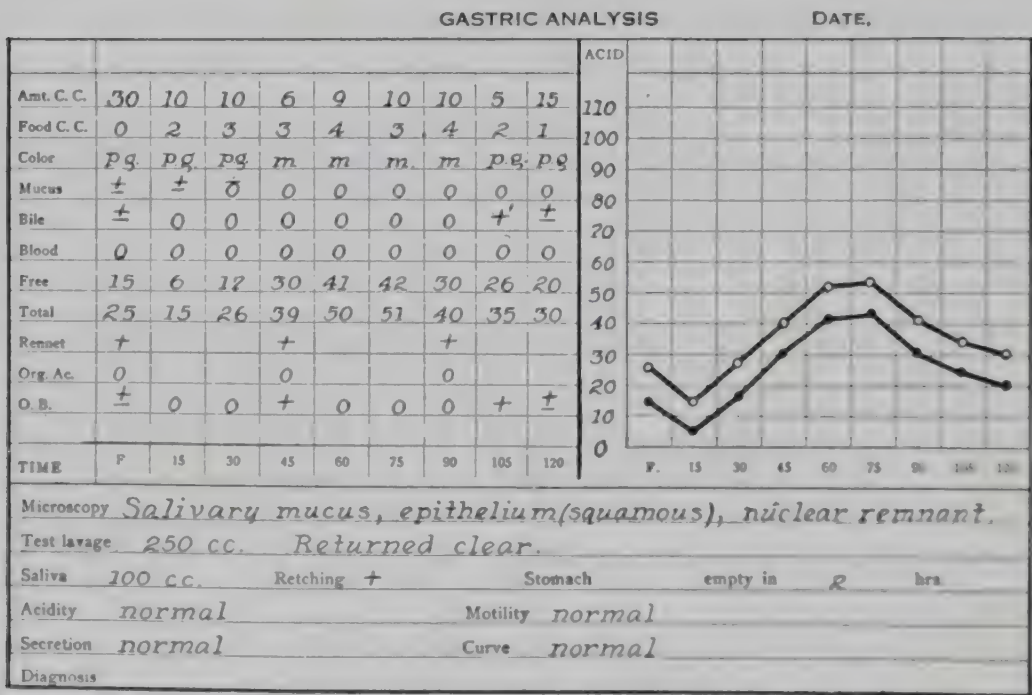


Fig. 64. Fractional gastric analysis chart used in routine practice. The solid line is free hydrochloric acid; the broken line, total acidity; p.g. designates pearl-gray; m., milky. The chart illustrates a normal gastric analysis. The acid values represent milliliters of 0.1N HCl in 100 ml. of the gastric specimen. (Bockus, H. L.: Gastro-Enterology, vol. 1.)

initial volumes of but 10 and 5.6 ml., respectively. There was no significant difference with respect to sex. The older age group tended to have larger residual volumes.

It is not uncommon in routine analysis to find too small an amount of residuum for satisfactory examination; *the average, however, is about 30 to 60 ml. in adults.*

After subcutaneous injection of histamine hydrochloride, 0.01 mg. per kilogram of body weight, in adults, the maximal ten-minute volume is approximately 37 ml. of juice at the age of twenty-five years, decreasing to 24 ml. at the age of sixty-five.<sup>4</sup>

*An adult man of average size secretes between 2000 and 3000 ml. of gastric juice in twenty-four hours.*<sup>25</sup>

The quantity of gastric juice in the adult rarely exceeds 50 ml. during the two-hour extraction in fractional analysis.<sup>1</sup>

**RATE OF FORMATION OF FASTING SECRETIONS.** The mean rate in children over the forty to fifty minute interval between passage of the tube and drinking the test meal in fifty-nine cases studied by Wolman<sup>32</sup> varied from 0.1 to 3 ml. per minute, with a mean of 0.84 ml. per minute and a standard deviation of 0.42. Wolman examined ninety-eight specimens from three infants six to eleven months of age and found the basal secretion to range from 0.1 to 0.9 ml. per minute with a mean of 0.31 and a standard deviation of 0.3 (see Table 140).

The volume of gastric juice one hour after an Ewald meal averages 50 to 100 ml.<sup>4</sup>

**ODOR.** Normal gastric juice has a pungent, penetrating odor.

**BILE.** The finding of bile in the gastric contents of normal adults is usually attributed to: (a) disease of the duodenum or gallbladder, (b) gagging and retching during intubation, or (c) reflux of alkaline duodenal juice as a normal physiologic mechanism.<sup>1</sup> Bile was demonstrable on at least one occasion in the gastric secretions of more than half of a group of fifty-nine children studied by Wolman.<sup>32</sup> He believes that this high incidence suggests that during childhood, just as in maturity, reverse peristalsis from the duodenum to the stomach is a common normal phenomenon.

**FOOD.** Gross food is not present in the fasting residuum. *Normally no more than 10 ml. of food should remain in the stomach at the end of a two hour Rehfuess test meal.*<sup>1</sup>

**MUCUS.** *Mucus is normally present.* Excessive amounts may be due to the swallowing of mucus with the tube. Swallowed mucus usually appears in large stringy gobs which float on the surface of the gastric juice. Microscopically, gastric mucus often appears as small, spherical snail-like bodies. Mucus from the gall tract is straw-yellow or greenish-yellow.

**BLOOD.** Gross blood is not normally present. Small quantities of bright red blood may be due to trauma to the mucous membrane from undue suction applied to the syringe. Occult blood<sup>3</sup> tests may be positive unless great care is taken to avoid traumatizing the mucosa when extracting the gastric contents.

**LEUKOCYTES.** *Leukocytes are often present in the normal residuum.* If the hydrochloric acid content is normal, the cytoplasm is digested, and only rem-

nants of the nucleus remain. Their presence may be due to swallowed exudate from the nasal, buccal or pharyngeal mucosa, or regurgitation of material from the duodenum.

**EPITHELIUM.** *Epithelial cells of some type are usually present.* A few squamous cells are almost always present, having been swallowed during passage of the tube.

**BACTERIA.** The normal flora is usually composed of organisms found in the mouth, nasal passages and upper respiratory tract. The richness of the flora increases as the acid secretion in the stomach diminishes. Cultures are usually sterile if the gastric acidity is normal or high.

**HYDROGEN ION CONCENTRATION (pH).** Wolman<sup>32</sup> examined the fasting secretions from fifty-nine children three to fourteen years of age and found the pH to range from 0.9 to 7.7. The mean for all readings was 3.27, with a standard deviation of 2.01. Many specimens were strongly acid, pH 1.3 or lower. Griswold and Shohl<sup>7</sup> studied the fasting secretion of twenty-five unfed normal newborn infants and found the pH to range from 1.7 to 4.4. The gastric contents removed one hour after the test meal from the same infants at the age of five days and at the age of ten days had a pH ranging from 2 to 2.8 and 2.1 to 3, respectively. Ritter,<sup>34</sup> in a study of thirty-six infants ranging in age from one-half hour to fourteen hours, found the pH range to be 1.28 to 4.59.

Gastric juice of the adult, as obtained through stomach fistulas, has a pH of  $1.2 \pm 0.3$ , and 1.3 to 2.5 at the height of digestion of ordinary meals. The gastric juice from normal stomachs one hour after an Ewald meal has a pH of  $1.7 \pm 0.1$ .<sup>4</sup>

**HYDROCHLORIC ACID.** In spite of extensive studies and considerable data on gastric acidity, a normal level or range of acidity has not been established, owing to (1) the different stimulating properties of the test meals employed; (2) differences in technic employed; (3) the wide range of acidity reported in various groups considered to have normal stomachs.

The normal range of acid secretion is so wide that it includes those having *hyperacidity* and *hypoacidity* as well as those considered as having *normal acidity*. These terms, or any similar classification which indicates whether the values obtained are in the upper or lower part of the range, are useful, because in this and many other values the position within the normal range is often of clinical significance.

In routine diagnostic studies there are those who examine but one specimen after the test meal, usually at the end of one hour. Others prefer the fractional analysis so that a curve may be plotted which gives additional information about the secretory response to the test meal.

**CHILDREN.** Ritter<sup>34</sup> studied the fasting residuum of thirty-six newborn infants one-half to fourteen hours after birth, and found the total acid to range from 11 to 84 units, and the free hydrochloric acid from 0 to 56 units. Miller<sup>35</sup> followed the fasting acid in fifty normal infants from birth to the end of the first month of age. The specimens were taken seven hours after the previous feeding. The highest values occurred on the first and second days; the acidity dropped until about the eighth to tenth day, at which time there was no free

id. From then on to the thirtieth day there was a gradual increase of the total acidity with a reappearance of free acid (see Table 139).

ADULTS. Some writers maintain that wide variations in the acidity of the gastric contents are frequently found in the same person from time to time.

TABLE 139

GASTRIC ACIDITY AFTER A TEST MEAL DURING THE FIRST MONTH OF AGE\*  
(Miller, 1941)<sup>21</sup>

Day	Number of Cases	Free Acid (mEq./L.)	Total Acid (mEq./L.)
.....	45	17.2	38.0
.....	40	15.4	37.9
.....	41	4.5	24.6
.....	40	1.0	21.7
.....	40	0.7	22.3
.....	40	0.2	17.6
.....	40	0.4	14.2
.....	41	0.0	14.2
.....	40	0.0	14.4
.....	40	0.0	11.7
0-15.....	41	0.7	13.8
6-20.....	50	1.0	16.9
1-30.....	45	2.1	18.0

\* A test meal is equal parts of breast milk and water, 60 minims per pound of body weight.

According to Bockus,<sup>1</sup> normal stomachs react similarly from day to day in so far as the acid response to a given meal is concerned unless some profound psychogenic or constitutional disturbance has intervened. A normal variation from

TABLE 140

FASTING SECRETIONS OF INFANTS\*  
(Wolman, 1946)<sup>32</sup>

	Range	Mean	Standard Deviation
Initial volume, ml.....	1.0-35	2.4	0.7
Basal secretion, ml./min.....	0.1-0.9	0.31	0.3
pH.....	1.3-7.5	4.4	2.1
Free acidity, mEq./L.....	0-50	8.6	12.3
Combined acidity, mEq./L.....	8-60	20.9	8.5
Total acidity, mEq./L.....	8-110	30.0	18.4
Pepsin, mg.....	0-2.8	0.9	1.23

\* Ninety-eight separate specimens from 3 infants aged 6 to 11 months.

day to day of 25 units is not unusual. Many persons with a normal postprandial acid curve show no free acid in the fasting content. In some cases the residuum may consist of nothing but swallowed saliva.

Vanzant and his co-workers,<sup>29</sup> who studied the influence of age and sex on gastric acidity, found the mean free acidity for men between twenty and forty

TABLE 141  
ANALYSIS OF GASTRIC JUICE OF CHILDREN  
(Wolman, 1946)<sup>32</sup>

Comparisons of Intragastric Responses to Milk Meals "Matched Pair" Data Broken down According to Three Different Variables											
Attribute	Comparison	No. of Experi- ments	Mean of Milks before Inges- tion	20	30	40	50	60	70	80	90
pH	All girls.....	34	....	5.8	5.2	4.4	3.6	3.2	3.0	2.7	2.7
	All boys.....	38	....	5.6	4.6	3.6	3.0	2.6	2.4	2.3	2.2
	All under 9.....	38	....	5.7	5.1	4.2	3.5	3.1	3.0	2.7	2.6
	All 9 and over.....	34	....	5.7	4.7	3.8	3.1	2.7	2.4	2.3	2.3
	All pasteurized.....	36	6.7	5.8	4.9	4.0	3.3	2.9	2.8	2.5	2.5
	All homogenized.....	36	6.7	5.6	4.9	4.0	3.3	2.9	2.7	2.5	2.4
	Mean.....	72	....	5.7	4.9	4.0	3.3	2.9	2.7	2.5	2.5
Total acidity, MEq./L.	All girls.....	34	....	31.5	35.1	39.6	45.4	49.3	53.2	55.2	56.5
	All boys.....	38	....	36.5	44.3	55.8	62.0	70.6	75.3	78.4	80.7
	All under 9.....	38	....	33.3	39.1	47.3	54.5	59.3	62.4	65.2	68.9
	All 9 and over.....	34	....	36.3	42.7	51.9	58.8	63.4	67.9	69.8	69.3
	All pasteurized.....	36	34.4	32.8	39.2	48.2	53.1	60.6	63.6	65.9	66.6
	All homogenized.....	36	35.8	36.9	42.4	50.6	57.1	61.7	67.2	70.1	72.1
	Mean.....	72	35.1	34.8	40.8	49.4	55.1	61.1	65.4	68.0	69.3
Free acidity, MEq./L.	All girls.....	34	....	0.0	0.4	3.7	8.0	12.4	16.2	17.7	18.3
	All boys.....	38	....	0.6	3.0	8.2	14.7	19.0	21.7	24.8	26.1
	All under 9.....	38	....	0.3	1.4	4.6	8.7	12.6	15.4	18.3	19.6
	All 9 and over.....	34	....	0.3	2.2	7.7	14.7	20.1	23.4	24.7	26.2
	All pasteurized.....	36	0	0.6	2.4	6.6	11.3	18.9	18.6	20.8	22.1
	All homogenized.....	36	0	0.0	1.0	5.4	10.9	15.8	19.3	21.6	23.2
	Mean.....	72	....	0.3	1.7	6.0	11.1	17.3	18.9	21.2	22.6

TABLE 142  
VOLUME AND ACIDITY OF GASTRIC JUICE OF CHILDREN AFTER HISTAMINE STIMULATION  
(Compiled from the literature by Wolman, 1944)<sup>32</sup>

Age	Secretory Volume (per minute) (cc.)	Free Acidity	Total Acidity	pH
Prematures.....	0.12-0.15	0	0- 8	4.7
Newborns.....	0.20-0.45	0- 20	15- 40	2.3-3.6
2 weeks to 6 months.....	0.25-1.10	0- 59	5- 71	1.5-3.4
7th to 12 months.....	0.40-1.50	12- 80	25-105	1.5-2.2
1 to 2 years.....	0.70-1.80	15- 95	26-106	1.2-2.0
2 to 5 years.....	0.50-2.20	29- 90	38-102	1.4-2.0
5 to 10 years.....	0.10-3.30	53-113	61-145	1.4-2.0
10 to 15 years.....	2.70-3.60	49-115	61-128	1.4-2.0

years of age to be about 47, with a standard deviation of 17; in the aged it falls off to a mean of 33, with a standard deviation of 17. The range for women was about 35 units during adult life, decreasing slightly after the age of sixty years.

TABLE 143  
ANALYSIS OF FASTING GASTRIC JUICE OF CHILDREN\*  
(Wolman, 1946)<sup>32</sup>

	Range	Mean	Standard Deviation
Volume (cc.)	0.4-80	8.7	8.2
Rate of formation (cc./Min.)	0.1-3	0.84	0.42
Hydrogen ion concentration (pH)	0.9-7.7	3.27	2.01
Total acidity when present (mEq./L.)	0-100	28.1	17.9
Combined acidity (mEq./L.)	4-40	19.6	6.2
Free acidity (mEq./L.)	4-126	38.2	21.6
Free acidity, Helmer-Fouts method (mg./cc.)	0-18.5	3.89	3.19
Free acidity from bile three-fourths of the time			

\* If all influences due to age and individual variation are ignored, the data for the child's fasting gastric juice at any single moment may be compressed into this general summary.

TABLE 144  
NORMAL RANGE OF HYDROCHLORIC ACID (FRACTIONAL ANALYSIS)  
(Bockus, 1943)<sup>1</sup>

Residuuum—Free acid: 5 to 25 units\*  
Total acid: 5 to 10 units higher than the free acid  
After a test meal—Free acid: 25 to 45 units  
Total acid: about 10 units higher than the free acid.

\* Units are the equivalent to the number of milliliters of  $N_{10}$  NaOH required to neutralize 1 ml. of gastric juice, using Töpfer's reagent (dimethyl-amino-azobenzene) as the indicator for the free acid and phenolphthalein for the total acidity.

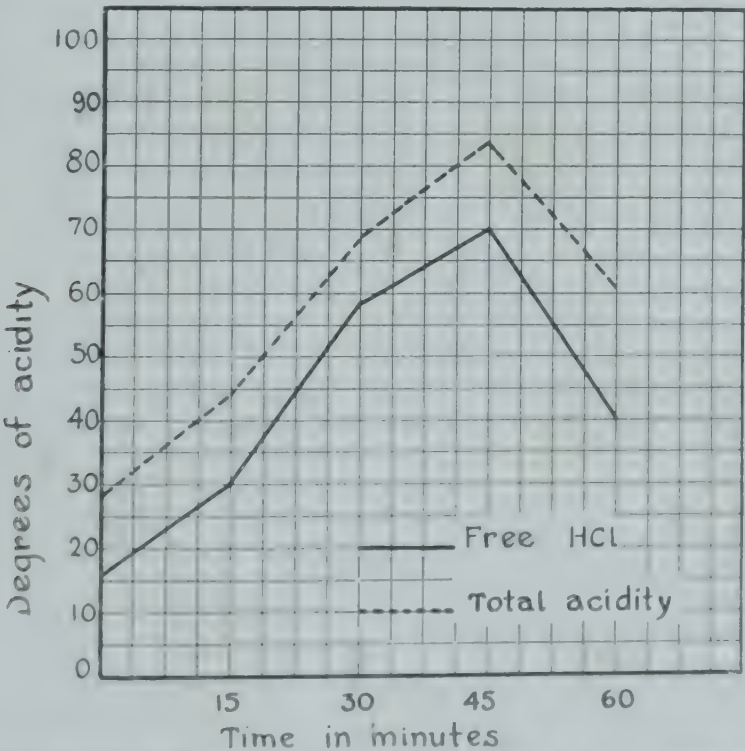


Fig. 65. Average normal acidity curves after an alcohol meal. (Data collected in the Hospital Laboratories of the Research and Educational Hospitals, Chicago. (Levinson, S. A., MacFate, R. P.: Clinical Laboratory Diagnosis, Lea & Febiger.)

The investigators employed the single extraction method with a test meal of arrowroot cookies and 40 ml. of water. Values were determined one hour after the test meal. Figure 66 and Table 145 show the values of normal acidity both sexes from twenty to seventy-nine years of age.

Lerman, Pierce and Brogan<sup>16</sup> studied gastric acidity relative to age and sex in 200 subjects (Fig. 67). Ruffin and Dick<sup>26</sup> studied the free hydrochloric acid in men and women and obtained results similar to those of Lerman and his colleagues (see Table 146).

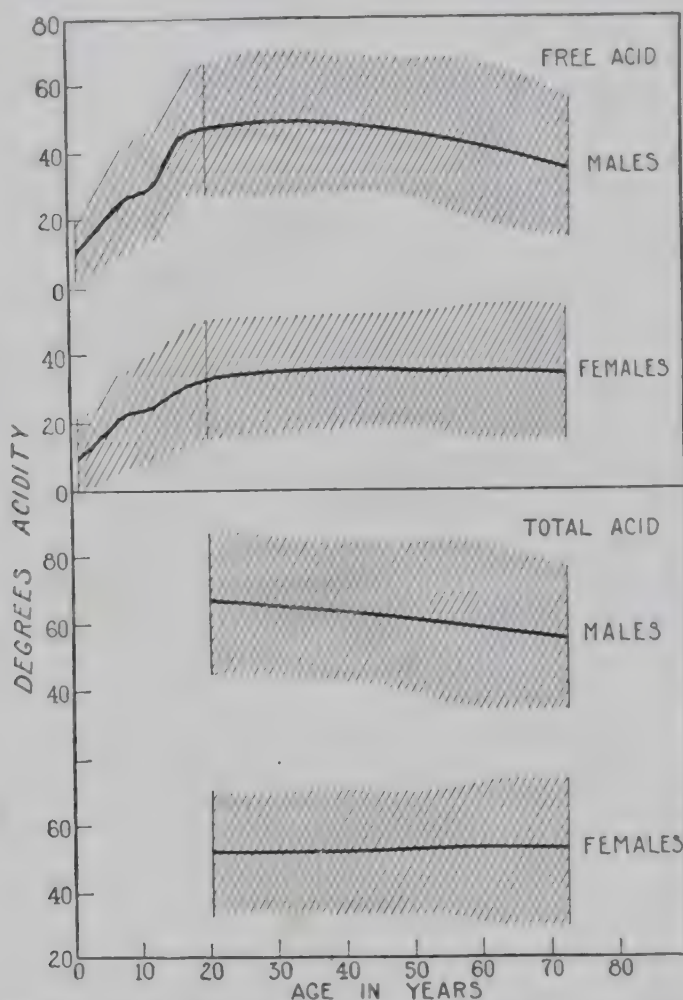


Fig. 66. Standards of normal gastric acidity. The shaded areas represent the limits within which lay 80 per cent of the data for free and total acid at the different ages. The heavy lines represent modes. (Vanzant, F. R., and others: Arch. Int. Med., vol. 49.)

There is some evidence of seasonal variations in gastric acidity in many persons. Vanzant and Alvarez<sup>28</sup> showed that the acid values were higher in the midspring, early autumn and midwinter. The variations were not great, amounting to 5 units in women and 7 units in men. Bockus<sup>1</sup> has also noted this same seasonal variation in certain patients during the spring and autumn months.

*A wide range of acidity must be considered normal.* Any person whose stomach is capable of secreting 20 or more units of hydrochloric acid after the standard meal may secrete maximal quantities of free acid after histamine stimulation.

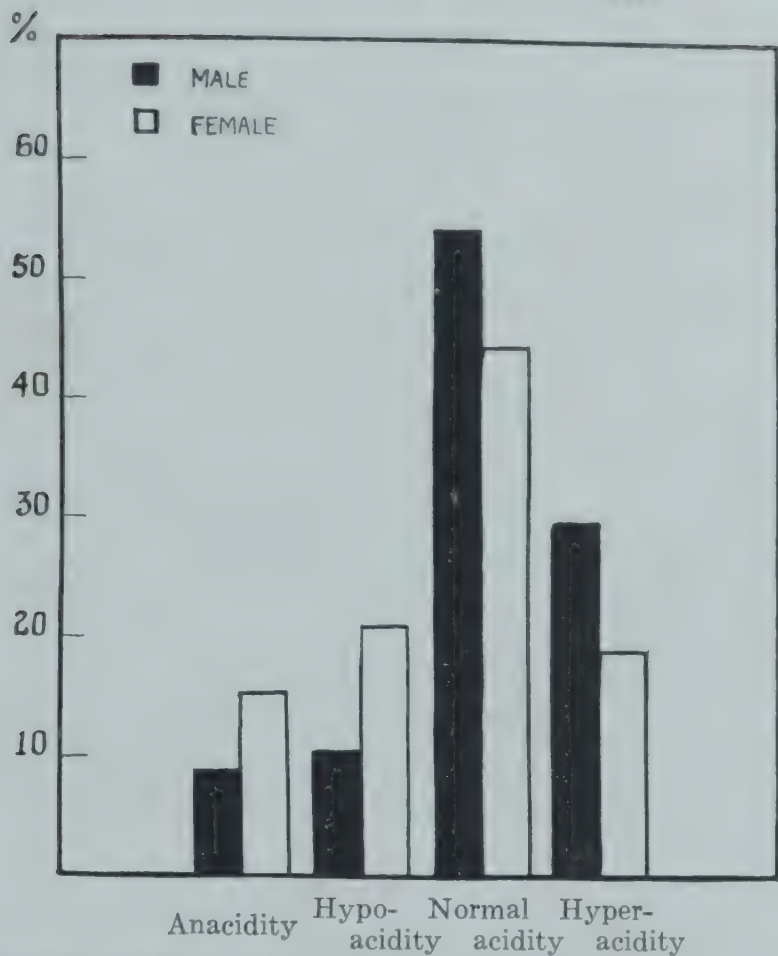


Fig. 67. Percentage incidence of the various degrees of acidity in normal male and female patients. The results are corrected for age distribution of men as compared to women. (Lerman, J., Pierce, F. D., and Brogan, A. J.: J. Clin. Investigation, vol. 11.)

TABLE 145

NORMAL STANDARDS FOR FREE AND TOTAL ACIDITY, VOLUME AND ACHLORHYDRIA OF ADULTS\*  
(Vanzant et al., 1933)<sup>29</sup>

Age	Males								Females							
	Free Acid (Units)		Total Acid (Units)		Volume (Cc.)		Achlor-hydia (Per Cent)		Free Acid (Units)		Total Acid (Units)		Volume (Cc.)		Achlor-hydia (Per Cent)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	True	Apparent	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	True	Apparent
0-24.....	46.7	16.5	63.5	16.5	118.0	49.5	.....	.....	32.0	14.5	49.7	14.5	100.5	39.0	2.0	3.0
5-29.....	47.0	17.0	63.0	16.2	116.5	50.5	.....	2.0	33.0	14.0	50.0	14.2	100.0	39.0	4.5	6.5
0-34.....	47.0	16.7	62.5	16.2	113.5	50.0	3.0	5.2	33.0	13.7	50.5	14.7	99.0	39.0	7.3	10.0
5-39.....	47.0	16.5	61.7	16.4	109.5	48.5	6.3	8.5	33.0	14.0	50.5	15.1	97.7	39.0	10.0	13.5
0-44.....	46.5	16.5	60.7	17.2	105.0	46.0	9.5	11.7	33.0	13.8	50.5	15.2	96.0	39.0	12.7	17.0
5-49.....	45.5	16.7	59.5	18.4	101.0	43.0	12.7	15.0	33.0	13.5	50.5	14.2	94.0	38.5	14.5	20.5
0-54.....	43.7	17.6	58.3	19.1	97.5	41.0	16.0	18.5	33.0	14.0	50.5	14.7	92.0	37.5	18.2	24.0
5-59.....	41.5	18.7	57.0	19.2	95.0	42.0	19.3	21.5	33.5	15.0	50.5	15.3	89.5	37.0	21.0	27.5
0-64.....	39.3	19.4	55.5	18.8	93.5	45.0	22.0	25.0	33.5	16.0	50.5	16.0	87.0	36.0	23.5	31.0
5-69.....	37.3	18.5	53.7	17.5	92.0	47.0	22.5	26.0	33.5	16.0	50.5	16.7	84.0	35.0	26.3	31.5
0-79.....	33.5	17.0	50.5	16.7	91.0	50.5	17.0	21.0	33.5	15.2	50.5	17.2	79.0	33.0	24.0	28.7

\* 3746 normal persons were studied. Test meals were 8 arrowroot cookies and 400 ml. of water. Values were determined one hour after the test meal.

TABLE 146

FREE ACIDITY OF GASTRIC SECRETION (DISTRIBUTION ACCORDING TO AGE,<sup>a</sup>  
(After Ruffin and Dick, 1939)<sup>21</sup>

Normal Men

Gastric Acidity (mEq./L.)	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	Total	Per- centage
1- 10 .....	..	3	7	14	7	7	..	..	..	38	4.5
11- 20 .....	..	3	14	17	10	8	4	2	1	59	7.0
21- 30 .....	..	1	16	13	9	12	1	..	..	52	6.2
31- 40 .....	..	7	26	34	14	8	9	1	..	99	11.8
41- 50 .....	..	4	31	29	30	16	8	..	..	118	14.0
51- 60 .....	..	6	26	30	27	11	6	3	..	109	13.0
61- 70 .....	..	6	32	29	29	15	2	..	..	113	13.4
71- 80 .....	..	3	28	36	16	10	2	1	..	96	11.4
81- 90 .....	..	6	17	19	14	17	3	2	..	78	9.3
91-100 .....	..	4	9	14	12	7	2	1	..	49	5.8
101-110 .....	..	2	6	3	8	3	1	..	..	23	2.7
111-120 .....	..	..	2	1	3	..	2	..	..	8	0.9
121-130 .....	..	..	..	..	..	..	..	..	..	..	..
Total.....	..	45	214	239	179	114	40	10	1	842	
Mean.....	..	58.2	55.9	54.0	58.8	55.4	54.0				
Standard deviation...	..	27.9	22.3	25.6	25.1	28.9	26.6				
Coefficient of variation...	..	42	40	47	43	52	49				

Normal Women

1- 10 .....	..	4	8	10	11	8	7	..	..	48	5.6
11- 20 .....	1	4	17	22	21	15	9	..	..	89	10.3
21- 30 .....	1	2	22	27	17	13	6	..	..	88	10.2
31- 40 .....	..	3	27	34	27	27	8	2	..	128	14.8
41- 50 .....	..	8	32	36	31	15	4	..	..	126	14.6
51- 60 .....	..	5	40	38	20	23	6	3	..	135	15.6
61- 70 .....	1	3	20	28	28	9	3	..	..	92	10.6
71- 80 .....	..	3	11	12	13	20	3	..	..	62	7.2
81- 90 .....	..	..	8	14	15	14	1	..	..	52	6.0
91-100 .....	..	1	..	5	10	2	7	..	..	25	2.9
101-110 .....	..	..	3	2	3	3	3	..	..	14	1.6
111-120 .....	..	..	1	2	1	..	..	..	..	4	0.5
121-130 .....	..	..	..	..	..	..	1	..	..	1	..
Total....	3	33	189	230	197	149	58	5	..	864	
Mean.....	..	42.9	46.3	47.4	50.4	49.6	45.5				
Standard deviation...	..	23.1	26.2	27.7	25.9	25.2	31.3				
Coefficient of variation...	..	54	59	58	51	51	69				

\* Values at 45 minutes after a test meal of 7% alcohol and 0.5 mg. of histamine. Tüpler's reagent was used as an indicator.

TABLE 147  
FREE HYDROCHLORIC ACID IN GASTRIC SECRETION\*  
(Ruffin and Dick, 1939)<sup>26</sup>

Age	Males			Females			Differ- ence of Mean	Stand- ard Error Differ- ence	Sig- nifi- cance†	
	Mean	Stand- ard Devi- ation	Num- ber of Cases	Mean	Stand- ard Devi- ation	Num- ber of Cases				
20.....	58.2	27.9	45	42.9	23.1	33	15.3	5.8	2.6	Significant
30.....	55.9	22.3	214	46.3	26.2	189	9.6	2.4	4.0	Significant
40.....	54.0	25.6	239	47.4	27.7	230	6.6	2.5	2.6	Significant
50.....	58.8	25.1	179	50.4	25.9	197	8.4	2.6	3.2	Significant
60.....	55.4	28.9	114	49.6	25.2	149	5.8	3.4	1.7	Not significant
70.....	54.0	26.6	40	45.5	31.3	58	8.5	5.9	1.4	Not significant

\* Values at 45 minutes after a test meal of 7% alcohol and 0.5 mg. of histamine. Töpfer's agent was used as an indicator.

† The figures in this column were obtained by dividing the difference of the mean by the standard error of the difference. If the value obtained is greater than 2, the difference of the means is significant, as indicated in the last column.

**HISTAMINE STIMULATION.** The principal value of the histamine test is to differentiate true achlorhydria from apparent, false or temporary achlorhydria. In persons with a normal acidity range after the bread and water meal, an injection of histamine will produce a further elevation in the free acid curve, but to a lesser extent than in those having a reduced acidity after the Ewald type of meal.

After histamine hydrochloride injection (0.01 mg.) subcutaneously, the maximal ten-minute volume is approximately 37 ml. of juice at the age of twenty-five years, decreasing to 24 ml. at the age of sixty-five. The maximum total acidity is approximately 90 to 67 units, respectively.<sup>4</sup>

**ORGANIC ACID.** Organic acid is not present in the residuum from the normal stomach after fasting.

**ENZYMES. RENNIN.** Wolman<sup>32</sup> calls attention to the erroneous concept widely held among physicians and implicitly subscribed to in many textbooks that the milk-clotting action of human gastric juice is a function of contained rennin. The ability of human gastric glands to elaborate true rennin has never been demonstrated. Gastric pepsin, and not a second ferment rennin, seems to be the agent responsible for the coagulation of ingested milk. Pepsin coagulates milk in the same manner as does rennin. Wolman also summarizes evidence which indicates that the human stomach does not secrete true rennin.

At the present time the ability of the stomach to secrete rennin is one of the routine tests in gastric analysis. The gastric juice is added to milk, and clotting, if it occurs, is assumed to be due to rennin. Normal secretions are expected to be positive in such tests when the acidity is less than pH 5.

Ivy<sup>14</sup> states: "Pepsin coagulates milk and no special milk-clotting enzyme (rennin) occurs in humans."

**PEPSIN.** This is a proteolytic enzyme secreted by the normal stomach which hydrolyzes native proteins. It coagulates milk and may be responsible for the clotting of milk when tests for rennin are conducted. Its optimum pH is approximately 2.0. Its activity is abolished above pH 5.0 and destroyed above pH 8.0. In the so-called rennin test of gastric juice, pepsin no doubt plays an important part or may be the enzyme responsible for the reactions obtained.

TABLE 148  
CHEMICAL CONSTITUENTS OF GASTRIC JUICE  
(Mattice, 1936)<sup>20</sup>

<i>Constituents</i>	<i>Mg./100 ml.</i>
Chlorides (as Cl).....	550
Free hydrochloric acid.....	200
Uric acid.....	0.8-2.0
Nonprotein nitrogen.....	20-48
Urea nitrogen plus ammonia nitrogen.....	7-14
Amino nitrogen.....	2-8
Volume in 24 hours.....	2-3 liters
Specific gravity.....	1.005
Water.....	99.4 per cent
Reaction (as pH).....	1.6-1.8

**CATHEPSIN.** This is a proteolytic enzyme found in gastric contents. It has an optimum pH of 4.7.<sup>6</sup>

**LIPASE.** This enzyme is present in the gastric juice of the newborn and appears to be constantly present through infancy and childhood.<sup>7, 12</sup> It is still uncertain whether the lipase present is secreted by the stomach or enters the stomach by duodenal regurgitation. Those who have studied this problem believe that the stomach secretes a lipolytic enzyme of weak potency. The optimum acidity for its activity is pH 4 to 5.

In adults lipase is secreted in minute amounts and has hardly any significance in gastric digestion.<sup>22</sup>

**UREASE.** According to Martin,<sup>19</sup> this enzyme occurs in normal gastric juice.

**INTRINSIC FACTOR.** The *intrinsic factor* is a substance secreted by the normal stomach which combines with the protein of ingested food (*extrinsic factor*) to form what has been designated as the "*erythrocytic maturing factor*," which is essential for the normal production of erythrocytes.

**CHLORIDE CONCENTRATION.** According to Wilhelmj and Sachs,<sup>11</sup> in the fundic juice the average chloride concentration is 578 mg. per 100 ml. of juice; in the pyloric and duodenal secretions, 345 mg. per 100 ml.; and in a mixture of the fundic and pyloroduodenal juices, between 340 and 578 mg. per 100 ml.

**INSULIN TEST.** This test is useful for detecting the presence of intact nerve fibers after vagus resection.<sup>13, 27</sup>

In the presence of the uncut vagus nerve, the curves for free and total acidity usually rise when the blood sugar level is depressed to 50 mg. per 100 ml. This is designated as a positive response. The height of the curves, the duration of the elevated portion and the latent period between the time of injection and

beginning of the rise all vary extensively. They may depend on the acidity rate of the fasting (preinjection) secretion, the idiosyncrasies of the subject, the degree of hypoglycemia and possibly even the rate of fall of the blood sugar (Fig. 68).

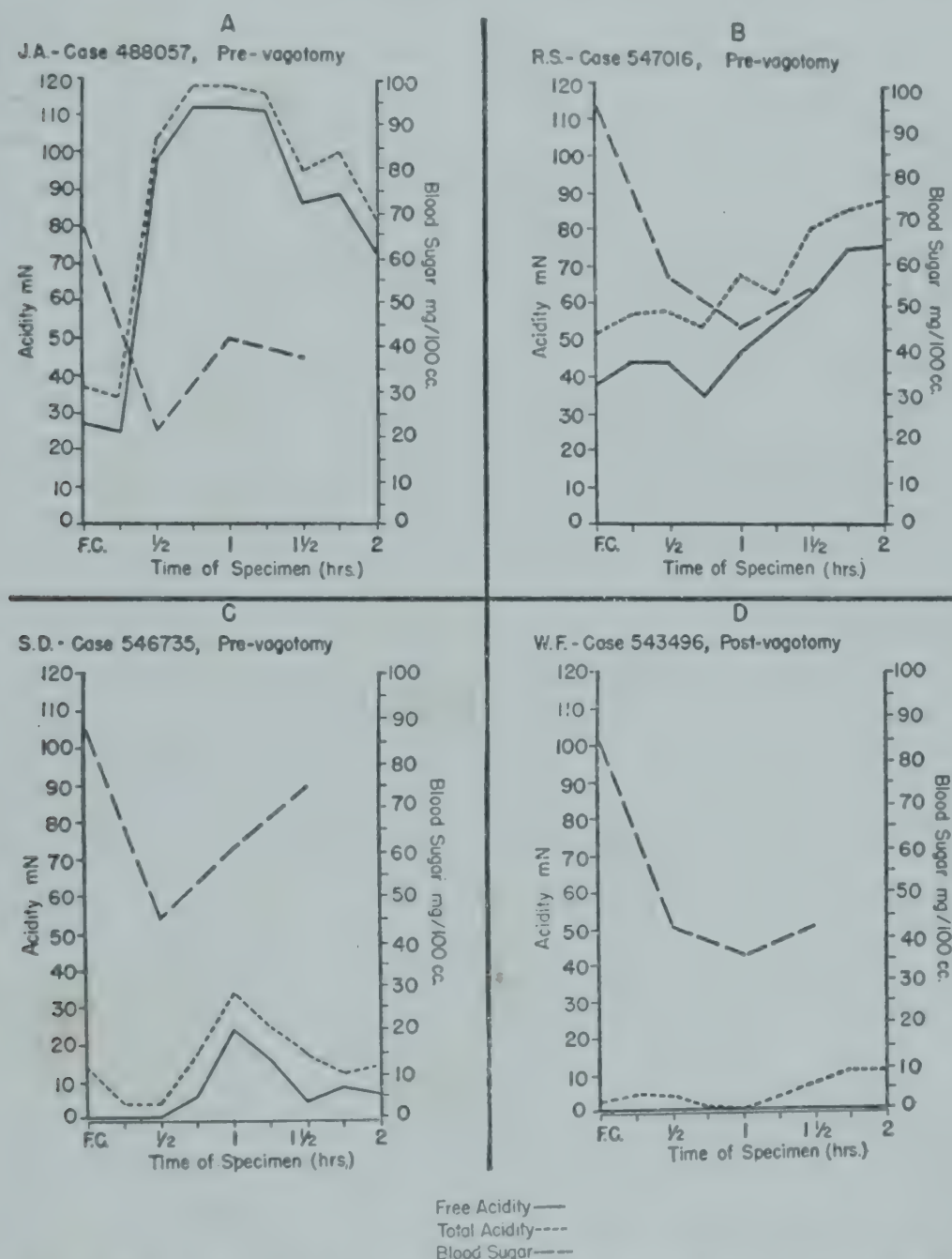


Fig. 68. Gastric acidity and blood sugar curves, illustrating various types of responses to the insulin test for the presence of uncut vagal fibers. (Hollander, F.: *Gastroenterology*, vol. 7.)

**GASTRIC EMPTYING TIME. NEWBORN AND INFANTS.** Owing to the great differences in the kind and size of the test meals and the methods employed, the findings of most investigators cannot be compared. In the newborn most of the meal has passed from the stomach in one and one-half to two hours; however, eighty of 110 infants studied by Henderson<sup>11</sup> displayed barium in the

TABLE 149

VARIATION OF EMPTYING TIME OF STOMACH OF INFANTS  
(Bouslog et al., 1935)<sup>1</sup>

<i>Emptying Time (Hours)</i>	<i>Number</i>	<i>Per Cent</i>
1½.....	5	2
1½-3.....	27	9
3-5.....	56	19
5-8.....	80	27
Over 8.....	123	43

TABLE 150

EVACUATION TIMES AND HIGHEST TOTAL ACIDITIES FOR VARIOUS ARTICLES OF DIET  
(Hawk et al., 1937)<sup>9</sup>

<i>Articles of Diet (100-Gram Portions unless Otherwise Stated)</i>	<i>Number of Observa- tions</i>	<i>Highest Total Acidity (Average) (cc. 0.1 N Alkali to Neutralize 100 cc. Juice)</i>	<i>Evacuation Time (Hours and Minutes (Average))</i>
Beef and beef products.....	25	120	3 00
Bread and cereals.....	75	80	2 40
Cakes.....	29	90	3 00
Chicken.....	20	125	3 15
Egg and egg combinations.....	90	80	2 40
Fish.....	75	130	2 50
Fruits.....	68	90	2 00
Gelatin (fruit juice preparations).....	5	70	2 00
Guinea hen.....	2	110	4 00
Ice cream.....	7	105	3 15
Ices.....	4	65	2 35
Junket.....	4	65	2 25
Lamb and lamb products.....	14	135	3 00
Licorice.....	1	65	3 00
Milk:			
Cow:			
400 cc.....	50	100	2 30
75 cc.....	3	45	1 15
Human:			
150 cc.....	5	60	1 40
225 cc.....	2	90	2 25
Nuts (25 to 50 grams).....	22	100	3 30
Orange-albumin (2:1).....	2	85	2 20
Pies.....	29	90	2 30
Popcorn.....	3	60	1 30
Pork and pork products.....	31	120	3 15
Puddings.....	23	90	2 20
Sugars and candies.....	28	70	2 05
Turkey.....	2	140	3 30
Veal:			
Market.....	7	140	2 50
"Bob".....	7	110	3 20
Vegetables prepared in different ways.....	124	75	2 15

each after eight hours, and thirty of those still had some remaining at forty-four hours.

Table 149 summarizes the results of a study of 133 infants. The test meal was routine milk feeding mixture with barium. In 244 out of 281 examinations food was present in the small intestine immediately after completion of the meal.<sup>2</sup>

**CHILDHOOD.** The emptying time of the stomach in children between four and thirteen years of age ranged from about 1.5 to six hours.<sup>3, 4, 5</sup>

The true emptying time may be obscure, because the estimation of the amount of barium residue appearing on the film is difficult. The residue in some cases appeared to be large, while in others it was only small. When the stomach showed only a few flakes, apparently adherent to the gastric mucosa, it was considered empty.

**ADULTS.** Mild exercise tends to hasten final emptying time, especially if it follows immediately upon ingestion of the meal. Violent and exhaustive exercise inhibits gastric peristalsis, but may be followed by a period of augmented activity so that the final emptying time is not much altered.<sup>1, 2</sup>

*The average emptying time of the normal stomach as tested by a water-barium meal varies between one and one-half and four hours.* An emptying time longer than six hours is definitely abnormal. In adults, age and sex do not affect the emptying time.<sup>5</sup>

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## Chapter 27

### THE SMALL INTESTINE

THE SMALL intestine is composed of the duodenum, the jejunum and the ileum. The duodenum is the shortest and the most fixed part; its length ranges from 10 to 30 cm., and its approximate width is 4 cm. It makes an almost complete loop from the pylorus to the duodenojejunal angle. The course of the duodenum varies in different persons, depending upon the habitus of the person and the length of its supporting structures. The configuration of the duodenum may resemble any of the following letters: C, V, L, U or O. For descriptive purposes the duodenum is divided into four sections: (1) first or superior portion, also called the duodenal bulb, (2) second or descending portion, (3) third or transverse portion, and (4) fourth or ascending portion.<sup>3</sup>

The jejunum, at necropsy, is about 8 feet long. It has a more abundant blood supply than has the duodenum, and its walls are thicker.

The ileum, at necropsy, is about 12 feet long. There is no sharp line of demarcation between the jejunum and the ileum.

Despite its length of 20 to 21 feet, the small intestine can be traversed completely by a tube 5 to 6 feet long. There is a gradual diminution in caliber toward the small intestine aborally. Usually the upper third or fourth of the mesenteric small intestine occupies the left upper quadrant of the abdomen, the middle portion occupies the central part, and the lower third is found in the hypogastrium and lower right quadrant of the abdomen.<sup>3</sup>

### MOTOR ACTIVITIES

1. TONUS. Ingelfinger and Abbott<sup>7</sup> found that the average content of air in a balloon at various levels of the small intestine was as follows: duodenum, 10 ml., jejunum, 24.5 ml., and ileum, 27 ml. The average volume in the terminal ileum was 19 ml.

2. RATE OF PROGRESS IN THE SMALL INTESTINE. (a) BISMUTH SUBCARBONATE MEAL. Using water containing 50 gm. of bismuth subcarbonate, David<sup>5</sup> found that the stomach was usually empty in from two and one-half to three hours, that the cecum began to fill in from two to four hours, and that the ileum was empty in six to eight hours.

(b) BARIUM MEAL. In Todd's<sup>10</sup> experience with 400 students, all the barium usually passed out of the ileum in eight to nine hours, sometimes in four hours. The passage of barium through the ileocecal sphincter began usually two and one-half hours after the meal was taken, occasionally within one and one-half hours.

(c) BALLOON. Ingelfinger and Abbott<sup>7</sup> found that the average time of passage of a balloon attached to a Miller-Abbott tube through the duodenum

was five minutes; through the jejunum, two hours; and through the ileum three to six hours. The time of passage of the balloon from the duodenum to cecum varied from four to nine hours.

CHEMICAL COMPOSITION OF SMALL INTESTINAL CONTENTS

1. HYDROGEN ION CONCENTRATION. Table 151 records values for pH at the various parts of the small intestine. The values by Breuhaus and Eyerly were obtained in situ by a small electrode which was swallowed. The others

TABLE 151  
pH OF SMALL INTESTINE IN FASTING SUBJECTS

Site	Distance beyond Pylorus in Cm.	pH Range	Number of Determinations	Investigator
Duodenum . . . . .	Bulb	5.60 (average)	22	Berk et al. (1942)
Duodenum . . . . .	9.6	5.67 (average)	18	Breuhaus and Eyerly
		5.74 (average)	18	(1943)
Duodenum . . . . .	...	4.70-6.50	6	Karr and Abbott (1935)
Jejunum . . . . .	60	7.03	1	Karr and Abbott (1935)
Upper ileum . . . . .	90	6.10	1	Karr and Abbott (1935)
Middle ileum . . . . .	120	6.77-7.21	4	Karr and Abbott (1935)
Lower ileum . . . . .	160	7.16-7.31	3	Karr and Abbott (1935)

TABLE 152  
OSMOTIC PRESSURE OF SMALL INTESTINAL SECRETIONS  
(Karr and Abbott, 1935)<sup>8</sup>

Level	Intubation (Number)	Rate of Flow (Cc. per Minute)	pH	Chlorides (mEq. per Liter)	HCO <sub>3</sub> <sup>-</sup> (mEq. per Liter)	Osmotic Pressure (milliosmols per Liter)
Duodenum . . . . .	III A	2.5	5.74	50.8		
	III B	0.88	5.52	75.4	5.8	162
	III C	0.76	5.93	85.6	21.1	214
	IV	1.42	4.70	93.4	4.3	196
	VIII A			62.4	6.3	138
	IX	0.37	6.50	132.6	5.1	276
	X	0.48	6.04	102.4	4.0	213
Jejunum (60 cm.) . . . . .	VI	1.00	7.03	116.4	5.8	244
Upper ileum (90 cm.) . . . . .	II A		6.10	128.6	2.3	262
Middle ileum (120 cm.) . . . . .	II B	0.40	7.05	132.6	6.5	278
	II C	1.05	7.21	126.0	20.1	292
	I	0.58	6.77	123.1	15.0	276
	V	0.72	7.15	101.0	17.8	238
	VII A	0.68	..	114.0	35.6	299
	VII B	0.18	..	104.6	39.8	289
	VIII B	0.28	..	127.0	3.9	262
Lower ileum (160 cm.) . . . . .	XI A	0.28	7.16	123.9	10.4	269
	XI B	5.8	7.21	128.2	16.5	289
	XI C	0.47	7.31	127.6	17.0	289

es were determined on samples aspirated by a Miller-Abbott tube or by specially constructed double-lumened tube.<sup>2</sup>

2. OSMOTIC PRESSURE. Karr and Abbott<sup>2</sup> determined the osmotic pressure of the small intestinal content in various parts after a fourteen to sixteen hour fast. The samples were aspirated by a Miller-Abbott tube (Table 152).

Table 153 gives values for osmotic pressure in fasting jejunal secretions in a larger series of cases.<sup>10</sup> These samples were also obtained by aspiration through a Miller-Abbott tube.

TABLE 153

## OSMOTIC PRESSURE OF FASTING JEJUNAL SECRETIONS\*

(From McGee and Hastings, 1945)<sup>10</sup>

$\text{HCO}_3$	Chloride	Total Base	Freezing Point Depression	Osmolar Concentration from Freezing Point Depressions		Osmolar Concentration	
				Per Kg. $\text{H}_2\text{O}$	Per Liter	$2 \times (\text{HCO}_3 + \text{Cl})$	$2 \times \text{total base}$
Eq. L.	(mEq./L.)	(mEq./L.)	°C.	(mEq./l.)	(mEq./l.)	(mEq./l.)	(mEq./l.)
2.....	80-139	110-162	.400-577	215-310	212-305	204-300	228-324

\* Twenty-five determinations on 18 subjects.

3. CHEMICAL COMPOSITION OF SMALL INTESTINAL CONTENT IN THE FASTING STATE. CALCIUM, TOTAL PHOSPHORUS AND TOTAL NITROGEN. Samples of small intestinal content of subjects after a fourteen to sixteen hour fast were obtained by a Miller-Abbott tube (Table 154).<sup>8</sup>

TABLE 154

## CONCENTRATION OF CALCIUM, NITROGEN AND PHOSPHORUS IN THE INTESTINAL CONTENTS OF FASTING SUBJECTS\*

(Karr and Abbott, 1935)<sup>8</sup>

	Range	Average
Calcium (mg./100 ml.)	5-12.8	7.7
Total phosphorus (mg./100 ml.)	4.5-13.2	6.8
Total nitrogen (mg./100 ml.)	35-200	53

\* Contents from the duodenum and contents ranging from 30 to 150 cm. from the pylorus were examined.

## ABSORPTION FROM THE SMALL INTESTINE

The introduction of the Miller-Abbott<sup>11</sup> technic of intestinal intubation has made possible studies of absorption in various parts of the intact small intestine.

1. ABSORPTION OF SUGARS. Glucose is absorbed rapidly and completely in the small intestine.<sup>1-13</sup> Groen<sup>1</sup> calculated the approximate absorption rate

per hour as 0.18 gm. per kilogram of body weight. Table 155 shows the absorption of glucose at different intestinal levels.

Galactose and levulose are also rapidly and completely absorbed by the small intestine.<sup>6, 13</sup>

The level of the intestines at which absorption takes place depends upon the amount and concentration of the ingested or instilled material.

TABLE 155

AMOUNT OF GLUCOSE ABSORBED AT DIFFERENT INTESTINAL LEVELS AFTER GASTRIC INSTALLATION OF VARIOUS CONCENTRATIONS

(Shay et al., 1940)<sup>15</sup>

Amount and Concentration of Glucose Meal	Amount and Per Cent of Total Glucose Absorbed			
	Duodenum	Upper Jejunum	Lower Jejunum	Ileum
13.5 gm. 5.4%	6.0 gm. 44%	10.9 gm. 81%	11.6 gm. 86%	13.1 gm. 90%
33.8 gm. 13.5%	12.8 gm. 38%	18.5 gm. 55%	24.3 gm. 72%	29.0 gm. 86%
62.5 gm. 25%	10.9 gm. 17%	38.9 gm. 62%	44.0 gm. 70%	52.4 gm. 84%

2. ASCORBIC ACID. Nicholson and Chornock<sup>14</sup> perfused 600 mg. of ascorbic acid in 600 cc. of water into the duodenum and upper jejunum. After one hour, 32 to 62 per cent was absorbed from this region.

3. AMINO ACIDS, GELATIN AND CASEIN. McGee and Emery<sup>9</sup> showed that

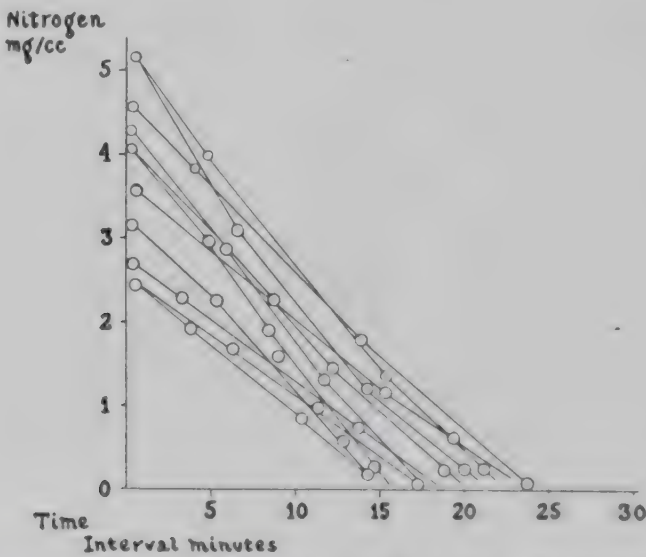


Fig. 69. Rate of absorption of amino acid mixture from the jejunum. McGee, L. C., and Emery, E. S.: Proc. Soc. Exper. Biol. & Med., vol. 45.

amino acid mixture was absorbed from the jejunum in fifteen to twenty-  
r minutes (Fig. 69). Figure 70 shows the absorption of casein and gelatin.

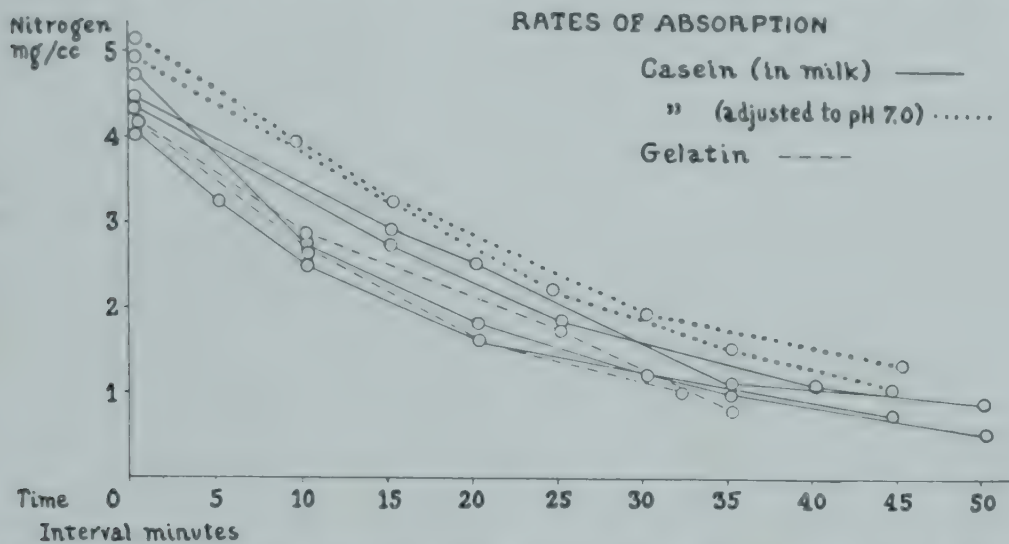


Fig. 70. Absorption of casein and gelatin from the jejunum. (McGee, L. C., and Emery, E. S.:  
Proc. Soc. Exper. Biol. & Med., vol. 45.)

PAIN REFERENCE FROM THE SMALL INTESTINE

Figure 71 depicts the sites of pain references from the small intestine. The  
pain was produced by distending a balloon at the end of a Miller-Abbott tube  
with air, the position of the balloon being checked fluoroscopically.<sup>12</sup>

Location of Balloon in Intestine Cm below Pylorus	Relation of Point of Pain to Location of Balloon in Abdomen with Reference to Umbilicus							
	Open Figures Represent cm; Enclosed Ones, Experiment Numbers							
Upper Jejunum 20-30 cm	(102)	(110)	(91)	(92)	(68)	(59)		
Lower Jejunum 60 cm.	(102)	(110)	(116)	(125)	(64)			
Upper Ileum 90-100 cm	(79)	(115)	(91)	(116)	(64)	(116)	(89)	(85)
Mid-Ileum 120 cm.	(79)	(115)	(106)	(116)	(67)	(102)	(60)	
Lower Ileum 150 cm.	(122)		(106)					

Fig. 71. Pain reference from the small intestine. In each square X represents the umbilicus,  
the location of the distended balloon in its relation to the umbilicus; and the point of the  
arrow, the location of the pain. The figures at the middle of the straight lines represent the  
distance in centimeters from the balloon to the point of pain. (Miller, T. G., Abbott, W. O.,  
and Karr, W. G.: Am. J. Digest. Dis., vol. 3.)

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## Chapter 28

### THE COLON

LENGTH of the colon varies from 125 to 200 cm., averaging approximately 150 cm. The cecum is the widest part, being about 7.5 cm. in diameter. There is a gradual decrease in the diameter of the large intestine from right to left, the smallest diameter being at the rectosigmoid.

The parts of the colon commonly referred to are the cecum, ascending, transverse, descending and sigmoid colon, and the rectum.

The colon can also be divided into two parts, functionally and according to its arterial blood supply and parasympathetic innervation. The right half, which arises from the embryonal midgut, is primarily concerned with absorption and reduction in volume of excreta, while the left half, which arises from the hindgut, is predominantly concerned with the storage and expulsion of feces. The proximal half receives its blood from the superior mesenteric artery, while the distal half is supplied by the inferior mesenteric artery and its branches. The vagus nerve supplies approximately the right half of the colon, while the parasympathetic innervation of the left half is supplied by the second, third and fourth sacral nerves.

The colon has four major functions: (*a*) absorption of water from the fluid material which enters it from the ileum, (*b*) storage of fecal content so that defecation can be performed on the average of once daily, (*c*) the expulsion of excreta by a series of coordinated muscular activities, and (*d*) the secretion of mucus which serves to protect the colonic mucosa from injury.

#### RATE OF PASSAGE OF MATERIAL THROUGH THE INTESTINAL CANAL

1. **PASSAGE OF BARIUM.** The time required for a barium meal to traverse completely the normal gastrointestinal tract, under roentgen observation, has been estimated as twenty-four hours,<sup>14</sup> twenty-four to forty-eight hours,<sup>10, 17, 23</sup> thirty-six to forty-eight hours,<sup>7</sup> fifty hours,<sup>11</sup> and seventy-two hours.<sup>5</sup> Alvarez and Freedlander<sup>2</sup> recovered and weighed fractions of a barium meal passed in the stools of normal adults and found that 75 per cent was expelled in seventy-two hours, the residue being passed in the succeeding four or five days.

The time required for the first part of a barium meal to pass from the stomach to the pelvic colon varies in different persons. The usual time is twelve to fourteen hours. The material begins to leave the stomach almost immediately after it has been swallowed; it moves steadily and at a fairly rapid rate through the duodenum and rapidly through the jejunum. Its progress through the ileum becomes slower as the ileocecal opening is approached, and in the lower part of the ileum the material tends to accumulate before it is passed into the cecum.

It begins to enter the cecum in an average time of two and one-half hours, about four hours it arrives at the hepatic flexure, in about six hours at the splenic flexure. Evacuation is at variable times after barium has begun to collect in the pelvic colon, but usually occurs sixteen to twenty-four hours after the meal has entered the stomach.<sup>4</sup>

The following figures have generally been accepted as representing the average normal rate for the passage of barium through the various segments of the alimentary canal:<sup>17</sup> Barium arrives at the cecum in four and one-half hours, in the hepatic flexure at six and one-half hours, in the splenic flexure at nine hours, in the iliac colon at eleven hours, in the pelvic colon at twelve hours and in the rectum at eighteen hours.<sup>6</sup>

TABLE 156  
RESULTS OF DAILY ROENTGEN EXAMINATIONS IN 52 SUBJECTS  
(Wallace et al., 1938)<sup>22</sup>

<i>Position of Column</i>	<i>6 Hours</i>	<i>24 Hours</i>	<i>48 Hours</i>	<i>72 Hours</i>	<i>96 Hours</i>	<i>120 Hours</i>
Head of barium column:						
Terminal ileum.....						
Cecum.....	8					
Ascending colon.....	8	2				
Transverse colon.....	30	4	1	1	1	Empty
Descending colon.....	4	7	3	2	1	
Sigmoid.....	2	8	7	..	3	
Rectum.....	..	17	17	11	2	
Tail of barium column:						
Terminal ileum.....	39	Tr 6	Tr 2			
Cecum.....	13	24	10	1	1	
Ascending colon.....	..	4	6	3	1	
Transverse colon.....	..	3	6	4	2	Empty
Descending colon.....	..	1	2	1	1	
Sigmoid.....	..	..	2	3	2	
Rectum.....	..	..	..	2	..	
Not examined.....	..	10	3	4	3	

Wallace and his co-workers<sup>22</sup> administered a motor meal consisting of 2 ounces of barium sulfate in cooked oatmeal to fifty-two ambulant ward patients free of gastrointestinal symptoms who did not have any other ailments which might affect gastrointestinal motility. The subjects had fasted for twelve hours and had had no cathartic for at least twenty-four hours. The position of the head and tail of the barium column was noted six hours after ingestion of the meal. Thereafter observations were made every twenty-four hours until evacuation was complete (Table 156).

In only a few cases was the entire meal expelled at one defecation; two or at times, three acts were necessary for its accomplishment. When the patient defecated, approximately the distal third of the colon was emptied and was not filled again until a mass movement occurred. Thus after defecation the position

the remaining column was not a true index of the motility of the column as a whole; hence an explanation for the great variation in the position of the head of the column recorded in the later hour examinations.

2. GLASS BEADS. Alvarez and Freedlander<sup>2</sup> studied the rate of passage of all glass beads (less than 2 mm. in diameter) through the intestinal tract of healthy men. Different-colored beads were given on each of three successive days. The beads recovered from the stools were counted. Great variations were found in the rate of passage of the beads. There was a rapid rate of 85 per cent in twenty-four hours, an average rate of 75 per cent in four days and a slow rate of 60 per cent in nine days. The persons with the faster rates had voluminous, soft, frothy and poorly digested stools, while those with the slower rates usually passed well-formed, often ovulated stools which showed evidences of good digestion.

TABLE 157

RATE OF PASSAGE OF INERT MATERIALS THROUGH THE DIGESTIVE TRACT  
(Hoelzel, 1930)<sup>16</sup>

Type of Material	Number of Determinations	Total Number of Pieces of Each Test Material	Per Cent Recovered	Average Rate of Passage (Hours)	Approximate Specific Gravity of Material
Gas (CO <sub>2</sub> )	...	.....	..	2-6	
Food	...	.....	..	25	0.9-1.6
Tomato seeds	6	75	100	25.44	
Almonds (cellulose)	40	930	99.37	26.76	1.45
Almond seeds	6	80	100	28.96	
Grape seeds	8	160	100	29.89	
Glass beads	30	800	99.63	40.15	2.60*
Travel	3	20	100	52.31	
Steel ball-bearings	3	20	100	79.98	7.70
Silver (bent wire)	4	35	100	81.88	10.53

\* The different-colored glass beads varied somewhat in specific gravity.

3. CARMINE. Mulinos<sup>10</sup> administered carmine to a group of 150 medical students and found that 38 per cent of them passed most of it with the first stool from six and one-half to forty-eight hours later. Half of the patients passed most of the dye with the second stool, nine to ninety-eight hours after ingestion. The greatest number passed the carmine after twenty-four hours.

4. VARIOUS INERT MATERIALS. Hoelzel<sup>16</sup> determined on himself the rate of passage of various inert materials through the digestive tract (Table 157).

5. PASSAGE TIME OF MILK IN INFANTS. The average gastrointestinal passage time in breast-fed "normal" infants is about fifteen hours; it varies from four to twenty-eight hours. The time is usually longer in bottle-fed infants because cow's milk tends to constipate.<sup>18</sup>

## PRESSURE IN SIGMOID

Using a balloon filled with water, Hines and his collaborators<sup>12</sup> found the pressure in the sigmoid of eleven normal medical students to average 18 (11 to 22) mm. of mercury.

## ABSORPTIVE FUNCTIONS OF THE COLON

Approximately 385 gm. of liquid chyme pass through the ileocolic sphincter daily,<sup>21</sup> while the weight of feces discharged from the rectum each day average about 135 gm. Most of the absorption ordinarily occurs in the right half of the colon, but studies of solutions introduced into isolated segments of the distal colon reveal that absorption can also occur in the distal half.

**ABSORPTION OF GLUCOSE ADMINISTERED BY PROCTOCLYSIS.** Pressman<sup>22</sup> administered 80 gm. of glucose in 250 ml. of water by rectum to seven fasting patients and noted an average drop of 14 mg. in the blood sugar level. This was interpreted as indicating that some glucose was absorbed, enough at least to stimulate insulin production, resulting in an increased metabolism of previously stored sugar, but the absorption by rectum had not been sufficiently rapid to replace the body sugars so destroyed. Analysis of the stools for sugar content revealed an average recovery of 24 per cent four hours after the introduction of the glucose solution.

To determine how much loss of glucose occurred as a result of destruction by fermentation, Pressman incubated glucose and feces for thirteen hours. At the end of seven hours destruction of nearly 90 per cent of the glucose had occurred.

Scott and Zweighaft<sup>21</sup> performed similar experiments and observed no increase in blood sugar when 400 ml. of 10 per cent dextrose were introduced by rectum. The returned enema in thirty-one of their fifty-four cases contained one-fourth or more of the administered glucose, and in five of the cases more than 50 per cent was returned. The absorption period was two and one-half to three hours.

QUANTITY OF COLONIC FLATUS EXCRETED IN  
TWENTY-FOUR HOURS

Table 158 gives the composition of colonic gases on various diets as recorded by Ruge. Fries,<sup>13</sup> using a single subject, estimated an average expulsion of 1000 ml. of gas per day, with single discharges of 50 to 500 ml. Analysis of a sample revealed carbon dioxide, 10.3 per cent; oxygen, 0.7 per cent; methane, 29.6 per cent; and nitrogen, 59.4 per cent.

PRESSURE REQUIRED TO RUPTURE VARIOUS PARTS  
OF THE INTESTINAL TRACT

Burt<sup>2</sup> submitted 5- to 6-inch sections of various parts of the intestinal tract obtained at necropsy from seven women and eleven men ranging in age from five and one-half months to eighty-two years, death having occurred

in various causes) to insufflation with compressed air and recorded the amount of pressure causing rupture. The average pressure required to perforate various parts of the intestinal canal, within and without the abdomen, was approximately 4.07 pounds per square inch. The intestines of children under twelve years of age withstood higher pressures than did those of older persons.

TABLE 158  
COMPOSITION OF COLONIC GASES (RUGE)  
(Alvarez, 1940)<sup>1</sup>

Gas	Milk Diet		Meat Diet			Diet of Legumes		
			After 24 Hrs.	After 48 Hrs.	After 72 Hrs.			
Carbon dioxide....	16.8	9.0	13.6	12.5	8.5	34.0	38.4	21.0
Methane.....	0.9	0.0	37.4	27.6	26.5	44.6	49.4	55.9
Hydrogen.....	43.9	54.8	3.0	2.1	0.7	2.3	1.6	4.0
Nitrogen.....	38.4	36.7	46.0	57.9	64.4	19.1	10.7	18.9

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## Chapter 29

### FECES

#### FREQUENCY OF DEFECATION

THE FREQUENCY of defecation in breast-fed infants during the first four months usually varies from two to four times daily; after this period the infant may be trained to defecate once daily. In a study of 527 males and 598 females nineteen to thirty years of age, 96 per cent of the males and 92 per cent of the females defecated one or more times daily, the remainder one to three times per week.

#### FORM AND CONSISTENCY

The form and consistency of the normal stool depend on the type of food ingested, its fluid content, the muscular tonus and size of the colon, the rate of passage of material through the intestinal tract, and the presence or absence of abnormality in the anal canal. *The average stool of the normal adult is 4 to 8 inches long and 1 to 1½ inches in diameter.* Usually its surface is rather smooth, but often it shows slight indentations.<sup>2</sup>

The diet greatly modifies the form and consistency. Usually the "vegetable eaters" pass large, thick and soft stools, whereas the "meat eaters" pass smaller, drier, often scybalous stools.

In a study correlating intestinal rate and form of the stool, Burnett<sup>1</sup> found that persons with an initial rate of fourteen hours and a final rate of sixty-two hours passed soft and formless stools; those with an initial rate of twenty-five hours and a final rate of ninety-seven hours passed formed stools with marks; while those with an initial rate of sixty-two hours and a final rate of 134 hours passed stools composed of units. The stools were marked with millet seed. The time of ingestion to time of appearance of the seeds was called the initial rate; the time of ingestion to the time the seeds were last seen was called the final rate.

#### COLOR (PIGMENTS)

The color of the stool is due chiefly to stercobilin, which is chemically identical to urobilin in urine. This is formed from bilirubin through the action of intestinal bacteria. The normal stool, in the absence of intestinal hypermotility, does not contain bilirubin. The normal stool, on standing, darkens in color, owing to the formation of urobilin. The type of diet and various medications may also cause variations in color.

Urobilinogen is a colorless reduction product of urobilin, and is excreted in both urine and feces. The normal amounts of urobilinogen excreted in feces are given in Table 165.

TABLE 159

INFLUENCE OF VARIOUS FOODS AND MEDICAMENTS ON THE COLOR OF THE STOOL  
(Bockus, 1946)<sup>2</sup>

<i>Material Ingested</i>	<i>Color of Stool</i>
Milk diet . . . . .	Light yellowish-brown
Meat protein . . . . .	Dark brown
Spinach . . . . .	Greenish
Carrots and beets . . . . .	Reddish
Chocolate, cocoa . . . . .	Dark red or deep brown
High fat diet . . . . .	Light brown
Blood . . . . .	Tarry black
Senna, rhubarb, santonin . . . . .	Yellowish
Calomel . . . . .	Greenish
Bismuth, iron, charcoal . . . . .	Black
Barium . . . . .	Milk-white

### ODOR

The normal stool of a person on a well-balanced diet has a characteristic and not too offensive odor. The ingestion of large amounts of meat or fish may render the odor more obnoxious. The stools of vegetarians have a less disagreeable odor, while those of persons on a pure milk diet are almost odorless.

### GROSS FOOD

Food remnants visible to the naked eye are rarely present in the formed stool of the normal person, except after the ingestion of excessive amounts of coarse fibrous vegetables such as corn or beets, or after hasty ingestion.

### MUCUS

Mucus cannot be recognized in the normal stool. Only small amounts are present on chemical analysis. In an analysis of 438 stool specimens of 126 healthy students between the ages of twenty and twenty-five years (120 males and 6 females), on an average uncontrolled diet, Fantus and his co-workers<sup>6</sup> found that the mucus content did not exceed 0.1 ml. of precipitate (from 30 per cent acetic acid) per gram of feces in 90.5 per cent of the cases.

### AMOUNT

**BULK.** The stool of the average normal adult on a mixed diet varies between 100 and 200 gm. In a group of thirty normal persons, Wozasek and Steigmann<sup>30</sup> found that the average weight of feces per day was 115 gm. In another group of fifteen cases the daily average was 52 gm. and at no time higher than 75 gm. In this smaller group the individual specimens were of low weight. The quantity of fecal output is diminished during fasting. Fasting men have been found to excrete as little as 7 to 8 gm. of feces per day.<sup>10</sup>

**DRY MATTER.** In the group of thirty cases just mentioned the dry matter varied from 23.61 to 30.17 gm.

**WATER CONTENT.** The water content of the stool of the average normal adult on a mixed diet is about 65 to 67 per cent (see Table 160).

TABLE 160  
WATER CONTENT OF HUMAN FECES  
(Steggerda, 1935)<sup>26</sup>

Subject	Number of Stools	Average Water Content		
		Part of Stool		
		Rectal (Per Cent)	Middle (Per Cent)	End (Per Cent)
1.....	7	71.05 (65.77-74.81)	81.69 (78.08-85.31)	82.61 (78.24-85.58)
2.....	5	62.60	73.18	72.24
3.....	6	72.56	80.03	82.24
4.....	6	64.81	71.63	72.40

CALORIC VALUE

In six subjects maintained on an intake of 2823 calories (carbohydrate, 140.5 gm.; protein, 97.5 gm.; and fat, 208 gm.) Wollaeger and his co-workers<sup>2</sup> found that the calories lost in the stools per day varied from a minimum of 70 (2.5 per cent of calories ingested) to a maximum of 140 (4.7 per cent of those ingested).

CHEMICAL COMPOSITION

**HYDROGEN ION CONCENTRATION.** The pH of fourteen stools of two subjects on mixed diets was between 6.9 and 7.7.<sup>20</sup> Measurements were made at room temperature.

The pH of one end of the stool may be different from that of the other by as much as 0.2 to 0.3. This is attributed to the longer contact of one end with the colon.<sup>20</sup>

FAT COMPOSITION

The fat composition of the stool of a normal person is not entirely of dietary origin, since even during starvation the stools contain fat. The part of the fecal fat contributed by the fat of ingested food depends on several factors, such as the digestibility of the ingested fat and its melting point. The fat content may go above 40 per cent without indicating an abnormal loss of fat.<sup>28</sup>

**FASTING SUBJECTS.** Muller<sup>17</sup> found in his studies on the fecal fat of two professional fasters, Cetti and Breithaupt, that the fatty material in the stool amounted to 0.57 to 1.3 gm. In Cetti the fatty material of the fasting feces amounted to about 36 per cent of the dry material, 39 per cent of which was neutral fat, 45 per cent fatty acid and 16 per cent cholesterol. In Breithaupt the fatty material comprised 28 per cent of the dry material, and, of this, neutral fat and cholesterol formed 47 per cent, fatty acids (and soaps) 53 per

(t. The percentage of total lipid material in the feces during the fasting period differed little from that observed when the subjects were not fasting.

NONFASTING SUBJECTS (ADULTS). AMOUNT OF FAT ON AN UNREGULATED DIET. Fowweather<sup>7</sup> analyzed the stools of eighty subjects (forty men and forty women), all hospital patients, but without evidence of gastrointestinal disease (table 161).

TABLE 161  
AMOUNT OF FAT IN FECES ON AN UNREGULATED DIET  
(Fowweather, 1926)<sup>7</sup>

	<i>Mean</i>	<i>Range</i>
Dry matter, per cent of fresh feces.....	21.1	4.6 -38.0
Total fat, per cent of dry matter.....	17.5	7.3 -27.6
Neutral fat, per cent of dry matter.....	7.3	2.5 -11.8
Neutral fat, per cent of total fat.....	42.0	24.6 -60.1
Free fatty acid, per cent of dry matter.....	5.6	1.05-10.0
Fatty acid, combined as soap, per cent of dry matter...	4.6	0.54-11.4

Values were obtained by the "wet" method.

TABLE 162  
FAT COMPOSITION OF STOOLS ON DIETS OF KNOWN FAT CONTENT  
(Adapted from Wollaeger et al., 1946)<sup>29</sup>

<i>Type of Diet</i>	<i>Fat in Diet (Grams)</i>	<i>Fat in Stool</i>	
		<i>Grams</i>	<i>Percentage of Fat Ingested</i>
Fasting	0	0.57-1.3	
Schmidt	111	4.26-4.6	
Mixed diet plus butter in varying amounts	4.2	2.4	57.1
	42.2	4.6	10.9
	80.2	5.1	6.36

TABLE 163  
FAT RETENTION ON COW'S MILK AND BREAST MILK  
(Holt et al., 1935)<sup>12</sup>

	<i>Percentage of Fat Intake Retained</i>	<i>Percent Distribution of Fecal Fats</i>		
		<i>Neutral Fat</i>	<i>Fatty Acid</i>	<i>Soap</i>
Average of 8 infants on breast milk	95.8	19.7	27.7	52.6
Average of 28 infants on cow's milk.....	90.7	9.6	14.4	76.0

FAT COMPOSITION OF STOOLS OF NORMAL INFANTS. In their studies on fat absorption in infants, Holt and his co-workers<sup>12</sup> reported values for the fat content of feces on diets containing varying amounts and different types of fat. Table 163 records values for fat content of the stools and also for the amount of fat absorbed.

For normal children on a mixed diet Parsons<sup>18</sup> claimed that the fat content of dried feces should not exceed 25 per cent and that a normal child on a mixed diet absorbs 94 to 98 per cent of the fat intake.

PROTEIN CONTENT

In an analysis of 438 stool specimens of 126 healthy students aged twenty to twenty-five years, Fantus and his co-workers<sup>6</sup> found that protein was absent in 99.3 per cent of the subjects.

NITROGEN COMPOSITION

The average amount of nitrogen excreted in the feces of a normal adult on a diet containing no excess of indigestible nitrogenous material or non-nitrogenous roughage usually amounts to 1 to 2 gm.<sup>19</sup> Wollaeger and his colleagues,<sup>20</sup> from the results of their studies of six subjects on a daily intake of 15.6 gm. of nitrogen, concluded that 2 gm. of nitrogen per day is the upper limit of normal. Schmidt and Strassburger<sup>21</sup> found that in subjects on the Schmidt diet the average fecal nitrogen was 0.99 gm. per day.

AMMONIA CONTENT

Robinson<sup>20</sup> reported values for the ammonia content of stools, ranging from 251 to 881 parts of ammonia per million. The ammonia was not uniformly distributed throughout the stools.

MINERALS

The most complete study of mineral balance in normal men is that of Clark,<sup>4</sup> whose data on excretion of cations and anions in the feces are given in Table 205 (p. 359).

TABLE 164  
PERCENTAGE OF TOTAL MINERALS EXCRETED IN URINE AND FECES  
(After Shohl, 1939)<sup>23</sup>

	<i>Urine</i> (Per Cent of Excretion)	<i>Feces</i> (Per Cent of Excretion)
Sodium.....	95	5
Potassium.....	79	21
Calcium.....	12	88
Magnesium.....	31	69
Chloride.....	98	2
Phosphorus.....	57	43
Sulfur.....	83	17

Although feces contain unabsorbable materials, they also contain materials that are excreted or secreted into the intestine. At the present time it is not possible to differentiate between those that are unabsorbed and those that are secreted. Table 164 gives the paths of excretion of minerals in the adult, expressed as percentage of the total excreted in the urine and feces.

LEAD. Lead in the feces normally ranges from 0.0 to 0.4 mg. per twenty-four hours (see Table 207a).

### TRACE ELEMENTS

Certain metals, once believed to be foreign to biological materials or possibly accidental in occurrence, are normal constituents of such materials. In Table 164a are given mean concentrations of manganese, lead, tin, aluminum, copper and silver which Kehoe and his associates found in the food and feces of a normal adult. The quantities of each of these metals found in their series of twenty-four hour samples of feces excreted approximated those found in the twenty-four hour samples of food ingested. This observation suggests that each of these metals is eliminated almost completely by the alimentary tract and is probably only scantily absorbed.

TABLE 164A

COMPARISON OF THE MEAN DAILY QUANTITIES OF TRACE METALS IN SUCCESSIVE SAMPLES OF THE FECES AND FOOD OF A NORMAL ADULT AMERICAN

(Kehoe, Cholak and Story, 1940)<sup>14a</sup>

	<i>Milligrams per 24-Hour Sample</i>					
	Mn	Pb	Sn	Al	Cu	Ag
Food						
Mean.....	4.28	0.290	17.14	36.43	2.32	0.088
Probable error.....	±0.43	±0.027	±1.30	±7.90	±0.28	±0.010
Standard deviation.....	±3.38	±0.213	±10.17	±61.97	±2.21	±0.077
Feces						
Mean.....	3.69	0.320	22.88	41.92	1.96	0.058
Probable error.....	±0.30	±0.019	±1.36	±6.19	±0.18	±0.005
Standard deviation.....	±2.30	±0.141	±10.28	±46.80	±1.33	±0.035

TABLE 165

UROBILINOGEN CONTENT OF FECES

<i>Peak</i>	<i>Limits</i>	<i>Investigator</i>
00-250 mg./24 hrs.....	40-280 mg./24 hrs.	Watson (1937)
50-300 mg./100 gm. stool...	70-600 mg./100 gm. stool	Sparkman (1939)
30-120 mg./100 gm. stool...	15-175 mg./100 gm. stool	Steigman and Dyniewicz (1943)
40-120 mg./24 hrs.....	20-200 mg./24 hrs.	Watson's method
50-185 mg./100 gm. stool...	20-220 mg./100 gm. stool	Steigman and Dyniewicz (1943)
60-200 mg./24 hrs.....	45-205 mg./24 hrs.	Sparkman's method

HISTAMINE CONTENT

Analysis of 500 to 600 gm. collections of feces yielded 6 to 20 mg. histamine.<sup>9</sup>

PANCREATIC ENZYMES

Amylase and trypsin are normally present in the stools; lipase usual cannot be detected, because it is inactivated by feces. Examination of the stool for enzymes is not a popular method for the study of the external secretion of the pancreas. The amylase content of the stools varies from day to day, depending upon the intake of food. Even with twenty-four hour samples there is no constant relationship between the amounts of amylase of patients on the same diet or of the same persons from day to day, although the weekly totals approximate each other more closely. The admixture of enzymes from salivary gland, stomach and intestine further contribute to the unreliability of determining fecal enzymes as a test of the external secretion of the pancreas.

TABLE 166

RÉSUMÉ OF CHEMICAL CONSTITUENTS OF FECES

<i>Substance</i>	<i>Amount</i>
Weight: Bulk.....	100-200 gm./24 hours
Dry matter.....	23.5-30.2 gm./24 hours
Water content.....	Average, 65-67 per cent
pH.....	6.9-7.7
Fat: Total.....	7.3-27.6% of dry matter
Neutral.....	2.5-11.8% of dry matter
Free fatty acid.....	1-10% of dry matter
Protein.....	Usually absent
Nitrogen.....	1-2 gm./24 hours
Ammonia.....	251-881 parts per million
Sodium.....	Average, 0.12 gm./24 hours (5 mEq.)
Potassium.....	Average, 0.47 gm./24 hours (12 mEq.)
Calcium.....	Average, 0.64 gm./24 hours (32 mEq.)
Magnesium.....	Average, 0.20 gm./24 hours (17 mEq.)
Chloride.....	Average, 0.09 gm./24 hours (3 mEq.)
Phosphorus.....	Average, 0.51 gm./24 hours (30 mEq.)
Sulfur.....	Average, 0.13 gm./24 hours (8 mEq.)
Lead.....	0-0.4 mg./24 hours
Urobilinogen.....	See Table 165
Histamine.....	See text
Enzymes.....	See text

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## Chapter 30

### THE LIVER

THE LIVER IS an irregular, wedge-shaped organ occupying the right uppermost part of the abdominal cavity. Its largest and thickest portion fits snugly under the right dome of the diaphragm, and its thinner part extends across the epigastrium into the left subdiaphragmatic region.

Although usually described as composed of five lobes, the division of the liver into two parts, on the basis of its embryology, is of greater physiologic significance. The right and left branches of the portal vein, hepatic artery and bile duct are separate and do not anastomose. The line of demarcation is not that of the falciform ligament, but corresponds to the embryologic boundary which cuts through the right lobe. The essential unit of the liver is the hepatic lobule.

**SIZE.** The liver is the largest gland in the body. Its size appears indicative not only of its many physiologic activities, but also of its capacity as a storehouse. Hepatic tissue is exceeded in amount only by voluntary muscle.

**WEIGHT.** The liver grows steadily up to the age of twenty years, after which time its weight remains fairly constant in both men and women. At birth its average weight is 135 gm.; by the first year its weight is more than doubled and by the third year is tripled. At puberty it is about ten times the birth weight. At the age of twenty-five years the median weight of the liver in the adult male is 1820 gm., gradually decreasing to 1480 gm. at the age of seventy-five years. The liver of the adult white female ranges from a median weight of 1460 gm. at the age of twenty years to 1430 gm. at the age of sixty, after which it decreases to 1180 gm. at the age of seventy-five.<sup>2</sup> (See also Table 327.)

**DIMENSIONS.** The dimensions of the normal liver of an adult are: transverse diameter, 8 to 9 inches; vertical, if measured on its right edge, 6 to 7 inches; anteroposterior diameter, measured at the level of the upper pole of the right kidney, 4 to 5 inches.

The lower edge of the liver in a normal adult is not evident on inspection, but in many children it is, especially during inspiration. The lower border can usually be felt at the end of inspiration at the outer border of the rectus, provided the abdominal wall is not too thick and the patient can relax well. Normally, the liver border is not palpable near or to the left of the midline unless the recti are widely separated or the abdominal wall is thin, since the edge of the normal left lobe, although uncovered by the ribs, is too thin to be palpable. In children and many women, especially multipara, much of the anterior surface of the liver may be palpated.<sup>3</sup>

**CHEMICAL COMPOSITION.** Few chemical analyses of the liver are available. The analyses which are available have been made on tissues obtained at lapar-

my or shortly after accidental death; they were accepted only if the livers were histologically normal.

**GLYCOGEN.** MacIntyre and his co-workers<sup>14</sup> found the glycogen content of livers to be 1.1 to 6.31 gm. per cent. Ravdin and his colleagues,<sup>15</sup> who studied sixteen livers, found a mean of 2.8 gm. per cent.

**FAT CONTENT.** Analyses of histologically normal livers for fat and its various fractions are more numerous than those for glycogen and protein.

In four patients with benign intestinal tract lesions, Ariel and his collaborators<sup>1</sup> found an average total lipid content of 11.82 (6.2 to 17.0) gm. per cent. The tissue was removed at laparotomy.

In sixteen patients Ravdin and his co-workers<sup>17</sup> found the mean fatty acid content to be 4.1 gm. per cent. The tissue was removed at laparotomy.

The values obtained for total liver lipids and the various lipid fractions on a group of twenty-five subjects killed in accidents in whom the livers were found to be normal are:<sup>16</sup>

Total lipids.....	2.42 to 8.50 gm. per cent
Fatty acids.....	1.62 to 7.22 gm. per cent
Neutral fat.....	0.63 to 6.5 gm. per cent
Phospholipids.....	1.46 to 3.03 gm. per cent
Cholesterol:	
Total.....	240 to 388 mg. per cent
Free.....	197 to 217 mg. per cent

**PROTEIN CONTENT.** The values obtained for the protein composition of four histologically normal livers are as follows:<sup>1</sup>

Total protein.....	11.4 to 16.6 gm. per cent
Albumin.....	3.9 to 4.7 gm. per cent
Globulin.....	6.7 to 12.7 gm. per cent

**PHOSPHATASE ACTIVITY.** The values for phosphatase activity of liver tissue in two children and two adults are given below.<sup>21</sup> The values represent milligrams of phosphorus split by 20 mg. of powdered tissue in twenty-four hours.

Alkaline phosphatase.....	0.425 to 5.63
Acid phosphatase.....	1.05 to 2.05

## LIVER BILE

The liver secretes bile as a continuous process. The chemical and physical characteristics of liver bile have been ascertained from samples obtained from fistulas—usually postoperative—of the various parts of the ductal system.

**QUANTITY OF SECRETION.** Sobotka<sup>22</sup> estimated the normal hepatic bile output in a person weighing 60 kg. to be 15 ml. per kilogram of body weight in twenty-four hours, i.e., 900 ml., or about 0.6 ml. per minute. The rate of bile secretion is greater during the waking than during the sleeping hours. Koster and his co-workers<sup>23</sup> found that the average rate of secretion during the waking hours was 24 ml. per hour and during the sleeping hours, 16 ml. per hour. They also found the total twenty-four hour output in relatively normal persons with complete biliary fistulas to range from 420 to 540 ml.

**SECRETORY PRESSURE.** Bile pressure readings in a patient with a T-tube in the common duct were reported to vary from 160 mm. during inspiration to 143 mm. during expiration.<sup>9</sup> Other workers have reported values ranging from 200 to 341 mm. of water.<sup>20</sup>

**SPECIFIC GRAVITY.** The specific gravity of liver bile has been reported to range from 1.008 to 1.015.<sup>4</sup>

**HYDROGEN ION CONCENTRATION.** The pH of bile obtained from the hepatic ducts has been reported as 7.1 to 7.3,<sup>18</sup> and 8.07 to 8.61.<sup>15</sup>

**FREEZING POINT.** The freezing point of liver bile varies from minus 0.56° to minus 0.61° C.<sup>19</sup>

**CHEMICAL COMPOSITION.** The chemical composition of bile varies in different persons. Table 167 gives the reported values of the various constituents based on analyses of samples of bile from various sources.

TABLE 167  
COMPOSITION OF LIVER BILE

		<i>Investigator</i>
Base . . . . .	80-90 mEq./L.	Walters and Snell (1940)
Bicarbonate . . . . .	20-25 mEq./L.	Walters and Snell (1940)
Bile acids:		
Total bile acids conjugated . . .	0.960-1.2%	Colp and Doubilet (1936)
Cholic acid . . . . .	0.393-0.626%	Colp and Doubilet (1936)
Desoxycholic acid . . . . .	0.85-0.881%	Colp and Doubilet (1936)
Total bile acids . . . . .	1.243-1.717%	Colp and Doubilet (1936)
Free bile acids . . . . .	0.283-0.517%	Colp and Doubilet (1936)
Bile salts . . . . .	20-30 mEq./L.	Walters and Snell (1940)
	0.5-1.0%	Lichtman (1942)
Bilirubin . . . . .	5-15 mg./100 ml.	Walters and Snell (1940)
	17-71 mg./100 ml.	Elton (1936)
	8-10 mg./100 ml.*	Elton (1936)
Calcium . . . . .	5-7 mEq./L.	Walters and Snell (1940)
	4-9 mg./100 ml.	Litchwitz and Bock (1915)
Cholesterol . . . . .	60-160 mg./100 ml.	Walters and Snell (1940)
	20-150 mg./100 ml.	Lichtman (1942)
Chloride . . . . .	90-100 mEq./L.	Walters and Snell (1940)
Fatty acids . . . . .	0.02-0.14%	Lichtman (1942)
Neutral fat and phosphatid . . . .	1/10,000	Lichtman (1942)
Sodium . . . . .	115 mg./100 gm.	Sobotka (1937)

\* Duodenal drainage specimen.

## HEPATIC BLOOD FLOW

Using the technic of hepatic venous catheterization and bromsulfalein clearance, Bradley and his associates<sup>3</sup> found that the estimated hepatic blood flow in twenty-three subjects without gross liver disease varied from 1085 to 1845 ml. per minute per 1.73 square meters of body surface, with an average of 1497 ml.

Using a similar technic, but with urea as a test substance, Myers<sup>14</sup> calculated the hepatic blood flow in normal young men as ranging from 750 to 1620 ml. per minute per square meter of body surface.

The hepatic blood flow decreases when the subject is tilted to the upright from a supine position. The decrease amounts to 15 to 60 per cent.<sup>8</sup>

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## Chapter 31

### LIVER FUNCTION TESTS

THE TERM "liver function test" is used in a broad sense, including procedures directly dependent upon one or more of the functions of the liver, and other tests based on more remote effects associated with deranged liver function.

#### SERUM BILIRUBIN

The detection of bilirubin in the serum depends upon the formation of a dye (azobilirubin) when sulfanilic acid and sodium nitrite (diazotizing reagent) are added to serum. When bilirubin which has been altered by passage through the liver cells is absorbed into the blood, the serum develops a reddish-violet color within thirty seconds after the addition of the diazo reagent. This is referred to as an *immediate direct qualitative van den Bergh reaction*. Serum bilirubin derived directly from hemoglobin combines with the diazo reagent only after precipitation of the proteins by alcohol or certain other agents. This is referred to as an *indirect van den Bergh reaction*. Normally, the qualitative van den Bergh reactions are negative, but a slightly positive indirect van den Bergh reaction may occasionally occur.

Quantitative determinations of serum bilirubin are frequently of value. These include determination of the *prompt direct reaction* (bilirubin which is read after one minute); *indirect reacting bilirubin* (quantitative indirect van den Bergh) and *total serum bilirubin* (including both direct and indirect reacting types).

As determined by the Malloy and Evelyn<sup>27</sup> method, the total serum bilirubin concentration usually ranges from 0.2 to 0.8 mg. per 100 ml. *Prompt direct reacting serum bilirubin (one minute) varies normally from 0 to 0.21 mg. per 100 ml.*<sup>31, 33, 51</sup> If the method of Thannhauser and Andersen<sup>48</sup> is used for determination of total bilirubin, the upper limit of normal is regarded as 0.2 mg. per 100 ml.

#### ICTERUS INDEX

The icterus index is obtained by comparing the yellow color of blood serum (usually due chiefly to bilirubin) with that of a standard solution of potassium dichromate in a 1:10,000 dilution. The method is subject to misinterpretation due to hemolysis or the occasional presence of significant amounts of other yellow pigments, such as carotene or lipids, in the serum. It becomes more specific by acetone extraction of extraneous substances, although this method may also remove some of the bilirubin. *By the water method, values up to 9 units are considered normal;*<sup>21</sup> by the acetone method the upper limit of normal is reported to be 4 to 6 units.

## BILIRUBIN TOLERANCE TEST

When bilirubin is injected intravenously in a dosage of 1 mg. per kilogram body weight, it is rapidly removed from the blood stream by the liver. This procedure is used to test the ability of the liver to excrete bilirubin. In Eilbott's<sup>15</sup> method the percentage of retention at the end of four hours is measured. *Normally, not more than 5 per cent of the injected bilirubin should be present in blood at the end of four hours.*

## EXCRETION OF UROBILINOGEN IN THE FECES AND URINE

Urobilinogen and other chromogens are formed in the intestinal tract by bacterial action on the bile pigments. For convenience these may all be considered under the term "urobilinogen." A certain part of the urobilinogen thus formed is reabsorbed into the portal circulation, and a varying amount may be excreted in the urine. The fate of the remainder is not certain.

Urobilinogen in the urine may be roughly estimated by the method of Wallace and Diamond<sup>19</sup> by means of the intensity of color developed when Ehrlich's reagent (para-aminobenzaldehyde in dilute hydrochloric acid) is added. The amount of urobilinogen may be expressed in terms of the highest dilution of urine giving a definite pink color with this reagent. *Normally, positive reactions may be obtained up to 1:20.*

Watson and his co-workers<sup>33</sup> have introduced a more accurate method for the quantitative estimation of urobilinogen in the urine based on the same principles, but utilizing the colorimetric measurement of the reaction. This method is applicable to the estimation of urobilinogen in both urine and feces. *Normal values given by these workers are 0.03 to 0.29 mg. per 100 ml. in the twenty-four hour urine specimen.* Watson and his collaborators also devised a simpler quantitative method, utilizing a two-hour urine specimen. In this procedure the results are expressed in "Ehrlich units" with a *normal range of 0.2 to 1.9 units.* In 90 per cent of normal cases the values were less than 1 unit.

Pellegrino and his colleagues,<sup>36</sup> using Watson's simplified method, found the mean value for urobilinogen excretion in the urine to be 0.3 Ehrlich unit per hour in thirty-nine normal persons. They discovered no definite cycle of excretion during the course of twenty-four hours.

In Watson's<sup>51</sup> method of extraction of a four-day feces collection *the normal values for fecal urobilinogen are from 50 to 280 mg. per day.* The simple quantitative method may be used; *normal values range from 75 to 333 Ehrlich units per 100 gm. of feces.*

## TESTS RELATED TO DYE EXCRETION

**EXCRETION OF BROMSULFALEIN.** The rate of disappearance of intravenously injected bromsulfalein (disodium-phenol tetrabromphthalein) from the blood may be used to evaluate liver function. Under normal conditions the dye is rapidly removed by the liver and excreted in the bile. In the presence of jaundice this procedure is difficult to interpret, since correct evaluation of the results depends on normal bile excretion.

Many modifications of technic have been suggested since this method was first used,<sup>9, 29, 40</sup> and many hold the view that if the results of this test are to be reliable, 5 mg. of dye per kilogram of body weight should be given intravenously. This amount more nearly taxes the capacity of the liver to excrete the dye than the older 2 mg. dose. The concentration of dye remaining in the blood plasma at the end of thirty or forty-five minutes is determined by comparison with standard dilutions of dye. In the absence of liver disease less than 10 per cent of the dye is retained in the blood at the end of thirty minutes; after forty-five minutes less than 6 per cent remains.<sup>9, 31, 34</sup>

Lippincott and his co-workers<sup>22</sup> found that 89 per cent of normal persons tested retained 2 per cent or less dye after forty-five minutes and 1 per cent retained more than 4 per cent after this interval. Mateer and his associates<sup>27, 28</sup> studied forty healthy doctors and nurses and found the retention after a 5 mg. dose of dye per kilogram of body weight to be between 0 and 4 per cent at forty-five minutes and between 0 and 3.3 per cent at sixty minutes.

**ROSE BENGAL TEST.** In this procedure 10 ml. of a 1 per cent solution of rose bengal (tetraiodotetrachlor-fluorescein) are injected intravenously. Samples of blood are obtained two and eight minutes after injection. *Normally, the concentration of the second sample should be only 50 per cent or less of that of the first sample.*<sup>12</sup>

**AZORUBIN S TEST.** This test depends upon the length of time required for azorubin S to appear in the bile after having been injected intravenously. A tube is passed into the duodenum and its position is confirmed fluoroscopically. When bile flow through the tube is established, 4 ml. of an aqueous solution of azorubin S are injected intravenously. Five minutes later 40 ml. of a 25 per cent solution of magnesium sulfate are introduced into the duodenum through the tube. The duodenal contents are collected in separate containers every one to two minutes thereafter until the specimens show a deep, cherry red color. *In the presence of normal biliary excretion this procedure measures the ability of the liver to excrete the dye.*

## TESTS RELATED TO CARBOHYDRATE METABOLISM

In general it may be said that the use of carbohydrates to test the functional capacity of the liver depends upon the fact that the metabolism of these and related substances and their conversion to glycogen are disturbed in the presence of impaired liver function. The tests depend upon the degree to which the carbohydrate disappears from the blood in a definite period after its administration.

**ORAL GALACTOSE TOLERANCE TEST.** The purpose of this procedure is to determine indirectly the degree to which galactose is converted to glycogen by the liver.

This method was originally introduced by Bauer.<sup>4</sup> Forty grams of galactose in 250 ml. or more of water are given orally, and the urine is collected hourly for five successive hours. Those specimens giving a positive qualitative test for sugar are combined, and the total amount of sugar excreted for the five-hour period is determined quantitatively. *The excretion of less than 2 gm. of galactose*

ing the test period is considered normal; between 2 and 3 gm. is borderline; more than 3 gm. is significantly increased.

There are numerous modifications of the oral galactose tolerance test. Althausen, Lockhart and Soley<sup>1</sup> measure the concentration of galactose in the blood thirty to sixty minutes after giving 50 gm. of galactose in 400 ml. of water. When this procedure is used, *the normal range of galactose in the blood is between 10 and 30 mg. per 100 ml.* Values above 40 and below 10 are considered abnormal.

For additional normal data, see Chapter 18.

**INTRAVENOUS GALACTOSE TOLERANCE TEST.** This procedure was devised by Bassett, Althausen and Coltrin<sup>3</sup> to avoid errors arising from variable absorption of galactose from the intestinal tract. One milliliter of a 50 per cent solution of galactose per kilogram of body weight is injected intravenously over a period of five minutes. Seventy-five minutes later the blood galactose level is determined. *In normal persons the blood is cleared of galactose in this period of time.*

For additional normal data, see Chapter 18.

**LEVULOSE TOLERANCE TEST.** The levulose tolerance test is sometimes used to evaluate liver function. The development of specific quantitative methods to determine levulose exclusive of glucose in the blood has made this a more dependable procedure than it was originally.<sup>19, 46</sup> Fifty grams of levulose are given orally. A fasting specimen is taken and levulose levels are determined at thirty minute intervals after the test dose. *In normal persons the concentration of blood levulose reaches a maximum of not more than 20 mg. per 100 ml. of blood within the first hour and falls below 10 mg. by the end of the second hour.*

For additional normal data, see Chapter 18.

**LACTIC ACID TEST.** In the presence of hepatic disease the conversion of l-lactic acid to glycogen by the liver is greatly impaired. After the intravenous administration of 75 mg. of sodium lactate per kilogram of body weight the blood lactic acid level rises and reaches a peak within five minutes. Thirty minutes after injection the level falls to within 5 mg. of the initial level.<sup>45</sup>

## TESTS DEPENDENT ON ALTERATION IN PROTEIN METABOLISM

Since the liver is concerned in the production of blood proteins, hepatic disease may result in either qualitative or quantitative changes in the albumin, globulin or fibrinogen. Actual quantitative alterations in these proteins, as determined by ordinary chemical methods, rarely occur unless liver disease is far advanced. It has been demonstrated, however, that the values for the separate globulin fractions are frequently altered and that qualitative changes in the albumin may occur in the presence of disturbed liver function. Several tests have been devised which measure indirectly these changes in the blood proteins.

(For "Normal Values for Serum Proteins," see Chapter 13.)

**CEPHALIN-CHOLESTEROL FLOCCULATION TEST.** This test depends upon flocculation of a cephalin-cholesterol emulsion which occurs in the presence of

changes in the albumin and gamma globulin fractions of the serum protein. Normal gamma globulin will produce such flocculation, but this effect is inhibited in normal serum by the presence of the serum albumin. In certain types of hepatic disease gamma globulin is increased and the inhibiting action of the albumin is decreased so that a positive cephalin-cholesterol flocculation is obtained.<sup>20, 30</sup>

The cephalin-cholesterol flocculation test was originally introduced by Hanger.<sup>18</sup> The degree of flocculation is estimated from 0 to 4 plus. *The majority of normal serums show little or no flocculation within forty-eight hours.* One plus or 2 plus reactions are seen occasionally in apparently normal persons.<sup>18, 20, 30.</sup> Mateer and his co-workers,<sup>28, 29</sup> in their study of forty healthy doctors and nurses, found only one subject with a 2 plus reaction; four had a 1 plus reaction and thirty-five had no reaction.

**THYMOL TURBIDITY AND THYMOL FLOCCULATION TESTS.** MacLagan<sup>30</sup> introduced the thymol turbidity test as a result of his observation that the serum of certain patients with hepatic disease showed definite turbidity within thirty minutes when added to a buffered thymol solution. If the serum is then allowed to stand, flocculation occurs. Neefe<sup>31</sup> has suggested that the test be modified to include a flocculation reading after eighteen hours, since in a few cases of liver disease there has been significant flocculation when the turbidity test was not altered. As in the cephalin-cholesterol flocculation, these phenomena apparently depend on alterations in the serum proteins, although the mechanism in the two procedures is not quite the same.<sup>31, 52</sup>

TABLE 168

INTERPRETATION OF CEPHALIN-CHOLESTEROL FLOCCULATION, THYMOL, AND COLLOIDAL GOLD RESPONSES

(Neefe, Bahnson and Reinhold, 1947)<sup>32</sup>

Test	Range of Readings (Visual)	Positive (Abnormal)
C24.....	0-4 +	1 + or greater
C48.....	0-4 +	2 + or greater
T30.....	0 units up	Over 3.0 units (visual reading)
TF.....	0-4 +	2 + or greater
T (T30 and TF).....	-	T30 over 3.0 units and/or TF 2 + or greater
CG.....	0-4 +	2 + or greater

C24 and C48 represent 24 and 48 hour readings of the cephalin-cholesterol flocculation reaction. T30, TF, T and CG refer, respectively, to the 30 minute thymol turbidity, the 18 hour thymol flocculation, the combined thymol (T30 and TF) and the colloidal gold reactions.

In MacLagan's method the thirty-minute turbidity is measured quantitatively by visual comparison with the turbidity standards of the Kingsburg-Clarke protein method, and the turbidity is reported in units. The degree of flocculation is read after eighteen hours and is graded from 1 plus to 4 plus.

*Normally, the thymol turbidity ranges from 0 to 4 units.*<sup>32, 33</sup> As reported by Neefe, thymol flocculations range up to 1 plus normally. Mateer and his colleagues found three subjects with 2 units, thirty-six with 1, and one with no units.

**COLLOIDAL GOLD TEST.** In this procedure it is apparent that certain qualitative or quantitative changes in the serum protein occurring in hepatic disease cause precipitation when the serum is mixed with colloidal gold suspension.<sup>11, 16</sup> The use of this procedure in liver disease was originally proposed by Gray;<sup>16</sup> the technic has been modified by Maclagan.<sup>25</sup>

*Serums from normal persons usually give negative reactions, although an occasional 1 plus reaction is obtained.*

**COLLOIDAL RED TEST.**<sup>26</sup> In this test a colloidal suspension of scarlet red (dan IV) is added to three different dilutions of serum. The principles of the test are similar to those of the colloidal gold test. Ducci<sup>13</sup> has modified the test, using but one dilution of serum, and regards the reactions the same as those obtained with colloidal gold.

**BLOOD PROTHROMBIN LEVEL.** Prothrombin is apparently formed almost wholly in the liver,<sup>2, 30</sup> and is now considered a part of the albumin fraction of the serum protein.<sup>35</sup> Maintenance of a normal prothrombin level in the blood largely depends on two factors: (a) adequate absorption of vitamin K from the intestinal tract, and (b) adequate formation of prothrombin by the liver. The former depends upon biliary excretion, since bile salts are necessary to the absorption of this fat-soluble vitamin. In the presence of adequate absorption of vitamin K a low prothrombin level may be regarded as indicative of disturbed liver function. *The normal prothrombin level is 70 to 100 per cent of a normal control (Quick's method).*<sup>7, 37</sup>

The prothrombin response test<sup>23, 24, 55</sup> may be carried out as a test of liver function when the blood prothrombin level is below normal. After determination of a subnormal prothrombin level, 2 to 5 mg. of vitamin K are administered parenterally on each of three successive days. The prothrombin is estimated daily during this period. If hepatic function is adequate and the prothrombin level lowered simply because of inadequate vitamin K absorption, the prothrombin level should rise significantly (more than 10 per cent) within twenty-four to forty-eight hours after the parenteral administration of vitamin K.<sup>35</sup>

Additional data on normal prothrombin time are on page 67.

**TYROSINE TOLERANCE TEST.** Impairment of the ability of the liver to metabolize the amino acid, tyrosine, is regarded as an indication of impaired hepatic function.

The procedure consists in the oral administration of 4 gm. of tyrosine and 1 gm. of casein in 250 ml. of water. Samples of blood are withdrawn fasting and one, two and three hours after ingestion of the amino acid solution. *Normal values are as follows: fasting blood tyrosine, 1.4 mg. per 100 ml. of blood; after one hour, 5.4 mg.; after two hours, 4.6 mg.; after three hours, 3.4 mg.*

## TESTS RELATED TO LIPID METABOLISM

**TOTAL AND ESTERIFIED SERUM CHOLESTEROL.** The liver is intimately concerned with the metabolism of cholesterol and apparently plays an important part in its esterification, so that the level of esterified cholesterol may be used as an indicator of liver function. The level of total cholesterol varies somewhat with the condition of the liver and especially with biliary excretions, but does

not detect the presence of liver damage, although it is occasionally lower with severe hepatic injury.

In the estimation of total and esterified cholesterol the method of Blo and Knudson<sup>6</sup> is commonly used. Other methods<sup>5, 10, 32</sup> are also satisfactory and are currently used. *The normal values for total cholesterol range from 160 to 190 mg. per 100 ml. of serum in most cases. Normally, from 65 to 75 per cent of the total cholesterol is in the esterified form, depending upon the method used.*

The normal blood lipids are considered in Chapter 15.

**ALKALINE PHOSPHATASE LEVEL.** The serum alkaline phosphatase is increased in diseases of the liver and biliary passages, particularly when jaundice is present.<sup>17, 39, 41, 47</sup> Whether the phosphatase level is influenced by failure of the damaged liver to excrete this enzyme or whether the damaged liver cells tend to release more than the normal amount of alkaline phosphatase, is not definitely known. The greatest increases tend to occur when biliary obstruction is present.

In estimating alkaline phosphatase the method of Bodansky<sup>8</sup> or the modification of Shinowara, Jones and Reinhart<sup>43</sup> is usually employed. The normal values for phosphatase in the serum are given in Chapter 22.

TESTS RELATED TO DETOXIFYING ACTIVITIES

Under normal conditions the liver is capable of oxidizing, reducing or conjugating certain compounds. This is referred to as a detoxifying function, although the exact nature of the mechanism is not always clear.

**HIPPURIC ACID SYNTHESIS.**<sup>37, 38, 44, 54</sup> Benzoic acid, administered in the form of the sodium salt, is converted by the liver to hippuric acid by conjugation with glycine. The sodium benzoate may be given orally or intravenously, the latter being the preferred method. Orally, 5.9 gm. of sodium benzoate are administered, and the amount of hippuric acid excreted in the urine during the following four hours is determined quantitatively. *Normally, 3 to 3.5 gm. are excreted; amounts less than 2.5 gm. are considered abnormal. In the intravenous procedure 1.77 gm. of sodium benzoate are given, and the hippuric acid excreted in the urine in one hour is measured. The normal amount is 1.0 gm. of hippuric acid.* An excretion of less than 0.7 gm. is an indication of liver dysfunction.

TABLE 169

RÉSUMÉ OF NORMAL VALUES FOR LIVER FUNCTION TESTS  
(Based on Values Obtained in the Laboratory of F. W. Sunderman)

Test	Values
Azorubin S.....	Appearance of dye in duodenal contents in 20 to 30 minutes
Bilirubin (serum).....	0.1 to 0.5 mg. per 100 ml. Newborn, 0.9 to 2.1 mg. per 100 ml.
Bilirubin tolerance test	Less than 5 per cent in blood stream after 4 hours
Bromsulfalein:	
2 mg. dose.....	No dye after 30 minutes
5 mg. dose.....	Less than 5 per cent dye after 45 minutes

Cephalin-cholesterol flocculation	Negative to plus 1
Cholesterol (total) serum	160 to 190 mg. per 100 ml.
Cholesterol-esterified	90 to 114 mg. per 100 ml.
Cholesterol esters as oleate and stearate	150 to 193 mg. per 100 ml.
Colloidal gold	Negative
Galactose tolerance test (oral):	
40 gm. in 250 ml. of water	Less than 2 gm. in 5 hours
40 gm. in 400 ml. of water	10 to 30 mg. per 100 ml. of blood
Galactose tolerance test (intravenous)	No galactose in blood after 75 minutes
Graham-Cole	Roentgen visualization of gallbladder 14 hours after taking the dye
Hippuric acid (oral)	2.5 to 3.5 gm.
(intravenous)	About 1.0 to 0.7 gm.
Icterus index	4 to 6 units
Lactic acid	Less than 5 mg. per 100 ml. of blood
Levulose (fructose) tolerance	Not more than 20 mg. per 100 ml. of blood within first hour; less than 10 mg. per 100 ml. of blood by end of second hour
Phosphatase (alkaline)	2.2 to 8.6 units (Shinowara, Reinhart and Jones)
Proteins (serum):	
Serum albumin	3.3 to 4.3 gm. per 100 ml.
Serum globulin	2.2 to 2.8 gm. per 100 ml.
Serum fibrinogen	0.3 to 0.4 gm. per 100 ml.
Albumin-globulin ratio	1.6 to 2
Prothrombin (blood)	11 to 12.5 seconds
Rose bengal	Not more than 50 per cent of the 2 minute value remains after 8 minutes
Takata-Ara reaction	Negative
Thymol flocculation	Negative to plus 1
Thymol turbidity	Less than 2.5 units
Urobilinogen (urine)	Daily excretion 0 to 3.5 mg. Positive up to 1 to 20 dilution
Urobilinogen (feces)	40 to 280 mg. per day

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## Chapter 32

### THE GALLBLADDER

THE GALLBLADDER is a distensible, pear-shaped sac averaging 7.5 by 2.8 cm. in its greatest diameters, and is connected to the common bile duct by the cystic duct. It consists of a rounded fundus, which often projects beyond the superior hepatic margin, a body, and a constricted neck that passes into the common bile duct. It normally contains about 50 ml. of concentrated bile.

The two primary functions of the gallbladder are the storage of bile for digestive purposes and the regulation of pressure conditions within the biliary system. In addition, the gallbladder secretes mucus.

#### GALLBLADDER BILE

Bile as secreted by the liver is normally a golden-yellow or light orange-colored fluid. The physical and chemical characteristics are changed after it has been subjected to the absorptive and concentrating mechanism of the gallbladder.

Greater variations in values for the constituents of gallbladder bile occur than for those of liver bile, because of variable concentration.

TABLE 170

#### COMPOSITION OF GALLBLADDER BILE

		<i>Investigator</i>
Base.....	280-300 mEq./L.	Walters and Snell (1940)
Bicarbonate.....	8-12 mEq./L.	Walters and Snell (1940)
Bile acids:		
Conjugated.....	6.16-8.32%	Colp and Doubilet (1936)
Cholic acid.....	3.33-4.25%	Colp and Doubilet (1936)
Desoxycholic acid.....	4.33-5.49%	Colp and Doubilet (1936)
Total bile acids.....	7.66-9.75%	Colp and Doubilet (1936)
Free bile acids.....	1.5-1.42%	Colp and Doubilet (1936)
Bile salts.....	150-210 mEq./L.	Walters and Snell (1940)
	2-9.7 gm./100 gm.	Lichtman (1942)
Bilirubin.....	80-135 mg./100 ml.	Walters and Snell (1940)
	50-1000 mg./100 ml.	Elton (1936)
	3.5-1786 mg./100 ml.*	Elton (1936)
Calcium.....	25-28 mEq./L.	Walters and Snell (1940)
Cholate-cholesterol ratio.....	10.5-11.1	Reinhold et al. (1937)
Cholesterol.....	160-260 mg./100 ml.	Walters and Snell (1940)
	5-600 mg./100 ml.	Lichtman (1942)
	260-540 mg. per cent	Reinhold et al. (1937)
Chloride.....	16-19 mEq./L.	Walters and Snell (1940)
Fatty acids.....	0.08-1.6 gm./100 ml.	Lichtman (1942)
Icteric index (U.).....	75-9900	Elton (1936)
	25-44,000*	Elton (1936)
Neutral fat and phosphatid....	Up to 1%	Lichtman (1942)

\* Necropsy specimens.

**COLOR.** The color of gallbladder bile varies from a dark golden-brown to black-brown or green-brown, depending on the degree to which it has been concentrated.

**SPECIFIC GRAVITY.** Values for specific gravity of gallbladder bile range from 1.012 to 1.014.<sup>9</sup> Elton<sup>7</sup> found the specific gravity of bile removed from the gallbladder of cadavers to range from 1.008 to 1.059.

**HYDROGEN ION CONCENTRATION.** The pH of gallbladder bile tends to be less alkaline than that of liver bile, and ranges from 6.9 to 7.7.<sup>13</sup>

Birch and Spong (1887) found the secretion of the gallbladder mucosa to be 20 to 30 ml. per day.<sup>10</sup> Mucoprotein in the form of mucin is present in bile in amounts of 1 to 4 per cent.

Hammarsten<sup>8</sup> reported the bile salt-cholesterol ratio in normal gallbladder to be 25 to 1. The critical ratio for the precipitation of cholesterol was reported as 18 to 1 by Newman,<sup>12</sup> and 13 to 1 by Andrews and his collaborators.<sup>1</sup>

The cholesterol in bile is in the free form; the ester fraction exists only in small amounts. No determinations for ester in normal patients have been encountered, though Riegel and her co-workers<sup>15</sup> found no ester present in ten specimens of bile obtained from pregnant women at the time of caesarean section.

### BILIARY DRAINAGE

Using the technic of collecting bile from the duodenum as described by Lyon,<sup>11</sup> Carter, Greene and Twiss<sup>5</sup> state that the amount of bile collected usually varies between 250 and 600 ml., fractions from 30 to 75 ml. being obtained after the different types of stimulation. The first or duodenal specimen (the "A" bile of Lyon) consists of 30 to 60 ml. of clear golden-yellow bile. After stimulation with magnesium sulfate the specimens are normally darker yellow or brownish, and of an increased viscosity. The thick, dark brown or green concentrated bile (the "B" bile of Lyon), usually 60 to 75 ml. in volume, may be obtained after use of either magnesium sulfate or olive oil. At the conclusion of the drainage there is frequently a light-yellow specimen of bile (the "C" bile of Lyon), which is often turbid in appearance and usually contains no sediment. Turbid bile, however, may occur at any time during the drainage and is usually associated with the presence of gastric contents.

### EVACUATION OF THE GALLBLADDER

**CHOLECYSTOGRAPHY.** Until recently the sodium salt of tetraiodophenolphthalein has been used for roentgen visualization of the gallbladder. It was administered either orally or intravenously. More recently beta (4-hydroxy-3, 5 di-iodophenyl) alpha phenyl propionic acid (priodax) has been used.

The normal gallbladder has been observed to evacuate in thirty minutes to six hours after a meal containing an adequate amount of fat. Boyden<sup>2</sup> gives sixteen minutes to four and one-half hours as the normal emptying time in man. However, gallbladders frequently remain partially filled from nine to twelve hours after stimulation.<sup>16</sup>

Boyden,<sup>2</sup> who studied the emptying time of the gallbladder in twenty-four subjects, found the minimum time required to empty all but three to be:

*Men:*

Range.....	11 to 140 minutes
Average.....	68.5 minutes

*Women:*

Range.....	48 to 216 minutes
Average.....	128 minutes

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## Chapter 33

### THE PANCREAS

THE PANCREAS is a flattened, retroperitoneal organ which lies upon the posterior wall of the abdomen and crosses the spine opposite the disk between the first and second lumbar vertebrae. It consists of an enlarged part on the right of the vertebral column, the head, and of a long body placed transversely, which is divided into the neck, body and tail. The head is embraced by the duodenum, the tail reaches over to touch the spleen.

The principal pancreatic duct, the *duct of Wirsung*, runs the entire length of the organ and curves down at its duodenal end to join the common bile duct in a common opening, the papilla of Vater, into the duodenum. An accessory duct, the *duct of Santorini*, present in a majority of persons, branches from the principal duct and enters the duodenum about 2 cm. above the papilla.

The pancreas is composed of two main types of cells, the acinar cells, which give rise to the external secretion of the pancreas, and the islet cells, which give rise to the internal secretion.

### PANCREATIC JUICE

PHYSICAL APPEARANCE. Pure pancreatic juice, obtained from a fistula, is a clear, watery, sometimes slightly opalescent fluid.

SPECIFIC GRAVITY. The specific gravity of pancreatic juice obtained from a fistula depends upon the state of hydration of the subject, as well as upon whether the mechanism responsible for its secretion at the time of collection of the sample is predominantly nervous or hormonal. *Values for specific gravity reported by various investigators range from 1.005 to 1.014 (20°-20°C.).*

TABLE 171  
CHEMICAL ANALYSIS OF PANCREATIC JUICE  
(Miller and Wiper, 1944)<sup>21</sup>

Sodium.....	138 mEq. per liter
Calcium.....	2.2-3.2 mEq. per liter
Chloride.....	60-80 mEq. per liter
Bicarbonate.....	60-75 mEq. per liter
Total protein.....	190-340 mg. per 100 ml.
Albumin.....	60 mg. per 100 ml.
Globulin.....	40 mg. per 100 ml.
Nonprotein nitrogen.....	14.3 mg. per 100 ml.
Urea nitrogen.....	5.0 mg. per 100 ml.
Uric acid.....	0.2 mg. per 100 ml.

(Nucleo-protein, cholesterol, sugar and sulfate were not present.)

HYDROGEN ION CONCENTRATION. The pH of pancreatic juice obtained from a fistula is always alkaline, and *the reported values range from 7.5 to 8.8.*

**TITRATABLE ALKALINITY.** The titratable alkalinity of pancreatic juice obtained from a fistula has been reported as equivalent to 65 ml. of N/10 alkali in 100 ml. of fluid, i. e., 65 mEq. per liter.<sup>19</sup>

**CHEMICAL COMPOSITION.** Table 171 gives the results of chemical analyses of pancreatic juice obtained from fistulas. Values reported by various authors vary considerably, and the reader is referred to the analyses by Kogut and his workers<sup>15</sup> and by Snyder and Lium.<sup>25</sup>

**VOLUME.** The secretion of pancreatic juice is continuous.<sup>8</sup> The volume flow is greater during the daytime than at night, however, and there is also a post-prandial increase.<sup>21-25</sup> The volume of flow also depends on the type of food ingested. In general, despite lack of uniform agreement, carbohydrates produce continuous flow, fats reduce the flow, and meats stimulate it.<sup>15</sup>

Considerable variations have been reported in the volumes of juice collected over a period of twenty-four hours. These variations are due to different degrees of completeness of the fistulas as well as to the degree of hydration of the patient. The commonly accepted average value for volume for twenty-four hours is 700 ml. *Normal values range from 30 to 1770 ml.*

TABLE 172

VOLUME, CONCENTRATION OF BICARBONATE, AND ENZYMES IN DUODENAL JUICE AFTER INJECTION OF SECRETIN\*

(Values from Comfort and Osterberg, 1940)<sup>6</sup>

Determination	Minute Periods	Range
Volume (in ml.)	0-10	21.0-52.0
	10-20	18.0-48.7
	20-30	15.0-53.0
	30-40	12.0-43.0
	40-60	6.0-59.7
	60-80	5.0-33.7
Bicarbonate (mM/ml.)	0-10	0.05- 0.10
	10-20	0.06- 0.15
	20-30	0.03- 0.15
	30-40	0.05- 0.17
	40-60	0.05- 0.17
Amylase (gm. maltose/ml.)	0-10	0.43- 1.89
	10-20	0.04- 0.60
	20-30	0.13- 0.95
	30-40	0.09- 1.03
	40-60	0.19- 1.55
	60-80	0.26- 1.52
Trypsin (ml. N/10 KOH/ml.)	0-10	0.60- 1.8
	10-20	0.20- 0.90
	20-30	0.30- 1.00
	30-40	0.70- 1.40
	40-60	0.40- 1.60
	60-80	0.20- 1.50
Lipase (ml. N/20 NaOH/ml.)	0-10	2-170
	10-20	1-101
	20-30	23-121
	30-40	2-129
	40-60	9-183
	60-80	41-140

\* Thirteen cases.

PANCREATIC ENZYMES IN DUODENAL JUICE

The concentration and the total amount of enzymes in duodenal juice may be determined by intubating the duodenum and aspirating duodenal juice. The usual procedure involves the introduction of a double tube, one lumen of which ends in the stomach and prevents gastric juice from entering the duodenum, and the other lumen in the duodenum. The basal secretion is collected for a definite period of time, after which a stimulant is administered. Numerous substances have been used to stimulate the pancreas; the two most widely used are secretin (hormonal secretion) and mecholyl (neural secretion). The amount and type of secretion produced by the two mechanisms differ. Stimulation with secretin produces a large volume of juice rich in bicarbonate, but poor in enzymes; mecholyl produces a scant flow of juice poor in bicarbonate, but rich in enzymes.<sup>6</sup>

TABLE 173

VOLUME AND CONCENTRATION OF ENZYMES IN DUODENAL JUICE AFTER INJECTION WITH MECHOLYL\*

(Adapted from Comfort and Osterberg, 1940)<sup>6</sup>

Determination	Minute Periods	Range
Volume (in ml.)	0-10	7.0-26.0
	10-20	3.0-31.6
	20-30	2.0-38.3
	30-40	1.0-13.9
	40-60	0.5-18.8
	60-80	2.0-65.0
Amylase (gm. maltose/ml.)	0-10	1.03- 6.19
	10-20	1.46- 5.68
	20-30	1.03- 5.51
	30-40	1.72- 5.85
	40-60	1.03- 5.85
	60-80	0.52- 5.16
Trypsin (ml. N/10 KOH/ml.)	0-10	1.7- 3.5
	10-20	2.1- 3.3
	20-30	1.3- 3.2
	30-40	0.6- 3.2
	40-60	0.7- 3.0
	60-80	1.4- 3.0
Lipase (ml. N/20 NaOH/ml.)	0-10	61-122
	10-20	78-154
	20-30	39-128
	30-40	34-200
	40-60	28-143
	60-80	71-152

\* Fifteen mg. of mecholyl injected subcutaneously; ten cases studied.

Comfort and Osterberg<sup>6</sup> determined the activity of duodenal contents by the method of Norby as modified by Agren and Lagerlof<sup>1</sup> and the tryptic activity by the procedure given by Agren and Lagerlof, which is the method outlined by Willstätter and his co-workers<sup>29</sup> and modified by Christiansen.<sup>8</sup> The activity of lipase was determined by the method of Cherry and Crandall<sup>3</sup> as modified by Comfort, Parker and Osterberg.<sup>7</sup> The values they found for fasting duodenal contents are:

Bicarbonate (mM/L)	1 to 30
Amylase (gm. of maltose/ml.)	0.34 to 1.72
Trypsin (ml. of N/10 KOH/ml.)	0.06 to 3.20
Lipase (ml. of N/20 NaOH/ml.)	5.5 to 267.0

Tables 172 and 173 give values after stimulation with secretin and mecholyl. Table 174 shows values after stimulation with olive oil.

TABLE 174

DUODENAL FLUID ANALYSES FOR PANCREATIC ENZYMES FROM 8 NORMAL SUBJECTS OVER 24-HOUR TEST PERIODS (AVERAGE VALUES, 288 TESTS)  
(Morrison, 1947)<sup>22</sup>

Enzyme	Fasting	20 Min. After Olive Oil Stim- ulation	40 Min. After Olive Oil Stim- ulation	60 Min. After Olive Oil Stim- ulation	Minimum Variation	Maximum Variation
Trypsinase*	2.5	3.0	4.2	4.9	0.6	7.4
Amylase†	5.2	6.4	8.2	10.1	0	17.3
Lipase‡	4.8	5.7	6.8	15.0	0	31.4

\* Milligrams tyrosine equivalent.  
† Milligrams glucose equivalent.  
‡ Milliliters 0.05 N sodium hydroxide equivalent.

INFANTS AND CHILDREN. Most of the published studies of pancreatic enzymes in infants and children have been made on "spontaneous" secretion of duodenal juice, using a single-lumen tube. Gastric content was aspirated before intubation of the duodenum, after which no effort was made to keep it out of the duodenum. Stimulants were not used. Table 175 contains values obtained by this procedure on normal subjects.

TABLE 175

PANCREATIC ENZYMES IN DUODENAL JUICE OF CHILDREN\*  
(Andersen, 1942)<sup>2</sup>

Age	Amylase Units per ml.		Trypsin Units per ml.		Lipase Units per 100 ml.	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
2 months	4.3	3.9	137.6	125.6	21.6	10.4
6 months	25.3	23.1	138.8	98.1	26.6	21.2
12 months	113.9	63.3	250.5	211.5	34.6	27.6
2 years	177.4	207.5	262.0	268.0	18.8	11.1
5 years	243.9	249.0	195.0	106.8	19.6	12.8

\* The volumes of duodenal juice aspirated varied from 6 to 8 ml. during a period varying from fifteen to sixty minutes. The viscometric methods were used for the determinations of trypsin<sup>24</sup> and amylase.<sup>27</sup> Lipase was determined by the method of Willstätter, Waldschmidt-itz and Memmen.<sup>20</sup>

## PANCREATIC ENZYMES IN BLOOD SERUM

The determination of the concentration of amylase and lipase in the blood serum has furnished valuable information. Little work has been done on the determination of trypsin in serum. Most workers do not accept the theory of pancreatic origin of the enzymes in the serum. Some have attempted to establish fractions from sources other than the pancreas.

**SERUM AMYLASE** (see Chapter 22, page 181). The amylase of whole blood is contained almost entirely in the plasma. The value for whole blood is approximately 60 per cent of that of serum or plasma.

Bernhard and Rosen<sup>3</sup> studied the distribution of amylase in serum, plasma, whole blood and erythrocytes of twenty-six human subjects. Their studies indicate that the erythrocytes contain no amylase and that the concentration in plasma is fairly constant for a given person.

Values for normal serum amylase concentration vary with the procedure used for its determination. The three most common methods have been related to the measurements of sugar fermentation, iodine titration, and viscosity. Normal values are given in Tables 114 and 176.

TABLE 176  
RANGE OF AMYLASE VALUES FOR NORMAL BLOOD SERUM BY VARIOUS METHODS

<i>Principle</i>	<i>Method or Modification</i>	<i>Range in Units</i>	<i>Investigator</i>
Viscometric . . .	Elman and McCaughan (1927)	4.2-7.2	Wakefield, McCaughan and McVicar (1930)
Saccharogenic.	Somogyi (1938)	60-180*	Somogyi (1941)
	Somogyi (1941)	80-180*	McCorkle and Goldman (1942)
Iodine . . . . .	Norby (1935)	0.0011-0.0071†	Lagerlof (1942)

\* Milligrams of sugar.

† Norby units.

Somogyi<sup>26</sup> studied 170 young and middle-aged adults and 1209 hospital patients who suffered from no condition likely to alter the diastase level. He found 80 per cent of healthy ambulatory adults to have blood diastase levels between 80 and 150; the remainder had levels falling either in the low range between 60 and 80, or in the high range between 150 and 180. Blood diastase values below 60 and above 200 are considered abnormal (Fig. 72).

**SERUM LIPASE.** The most widely used method for determining serum lipase has been the Cherry and Crandall<sup>4</sup> modification of the Loevenhart method, using an olive oil emulsion as a substrate. There is a wide variation in the top normal values reported by various workers. One of the reasons for the variations is the use of olive oil emulsions in which the size of the substrate particles varied. It is highly desirable that each batch of olive oil emulsion be standardized on a new set of normals so that abnormal values can be more correctly interpreted.

The olive oil method requires twenty-four hours for its completion. This is too long a time, however, when information is needed promptly. To overcome this objection, some workers have preferred to use tributyrin as a substrate.

When tributyrin is used, the test requires one hour for completion. The tributyrin method is subject to the criticism that it is not specific for lipase, in so far as it can be split by esterase, another enzyme which is also found in the blood serum.

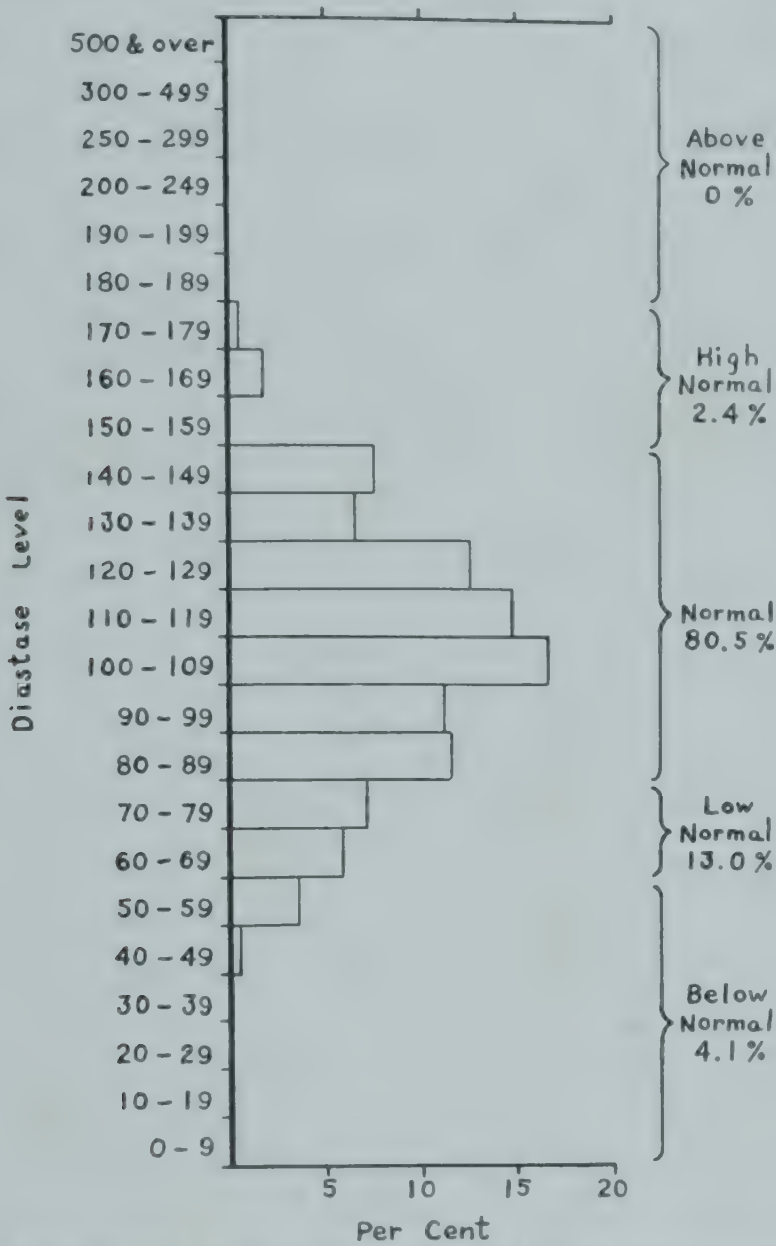


Fig. 72. Range of distribution of blood diastase values of healthy persons. Somogyi, M.: Arch. Int. Med., vol. 67.)

TABLE 177  
NORMAL VALUES OF SERUM LIPASE

Substrate	Upper Limit for Normals	Modification or Method	Investigator
olive oil	0.2 ml. N 20 NaOH	Cherry and Crandall (1932)	Crandall and Cherry (1932)
olive oil	1.0 ml. N 20 NaOH	Cherry and Crandall (1932)	Johnson and Bockus (1940)
olive oil	1.5 ml. N 20 NaOH	Cherry and Crandall (1932)	Comfort and Osterberg (1940)
tributyrin	35-112 U.	Goldstein and Roe (1943)	Goldstein and Roe (1943)

## PANCREATIC ENZYMES IN URINE

Amylase is the only pancreatic enzyme which has been determined in the urine for clinical purposes. The normal range varies considerably, and, according to Dozzi,<sup>8</sup> factors such as restriction or forcing of fluids, variations in the diet and changing the pH of the urine have little influence on the rate of excretion of urinary amylase.

Dozzi, using the Shaffer-Hartmann modification of the saccharogenic method, found the range in twelve normal subjects to be between 264 and 953 mg. of glucose in twenty-four hours.

Other methods of amylase determination have yielded values for top normal amylase excretion in the urine which were characteristic of the method employed. Lagerlöf<sup>16</sup> reported 0.055 Norby unit as the upper limit of normal when Norby's method (1935) was used. Foged,<sup>12</sup> using Fabricius-Moeller's method,<sup>11</sup> regarded 300 units as the upper limit of normal. A unit is defined as that solution, 1 ml. of which under given conditions (38° C. and thirty minutes) is able to break down 1 ml. of a 1 per cent solution of starch.

## CHEMICAL COMPONENTS

The external secretion of the pancreas is a faintly opalescent, colorless, strongly alkaline fluid that foams readily. The chemical composition is given in Table 178.

TABLE 178

## PANCREATIC JUICE (NORMAL VALUES)

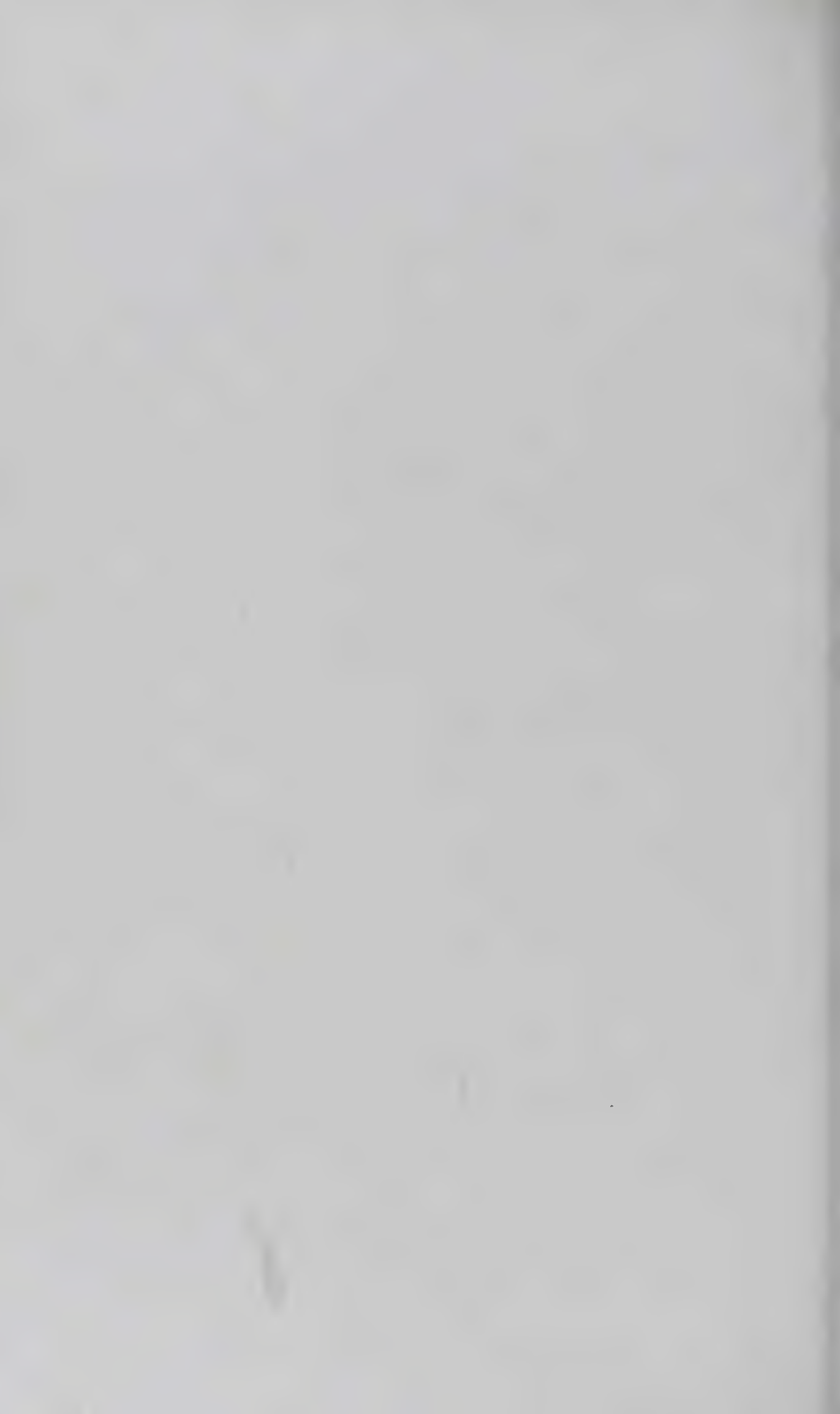
(Mattice, 1936)<sup>18</sup>

Volume.....	600-700 ml./24 hours
Specific gravity.....	1.007
Water.....	98.7%
Reaction (as pH).....	8.7-9.0
Urea nitrogen.....	10-15 mg. per 100 ml.
Ammonia nitrogen.....	10-15 mg. per 100 ml.
Calcium (as Ca).....	4.5 mg. per 100 ml.
Inorganic phosphorus.....	Less than 1 mg. per 100 ml.
Protein.....	1.2 gm. per 100 ml.
Albumin: globulin.....	1.2 gm. per 100 ml.
Sugar.....	None

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Section VI

THE NERVOUS SYSTEM

(Normal Values in Neurology)



## Chapter 34

### THE CRANIAL NERVES\*

#### OLFACTORY NERVE

THIS NERVE carries volatile stimuli from the schneiderian membrane in the upper nasal passages to the olfactory centers in the brain. One nostril is tested by closing the other with a finger, and a familiar volatile substance, such as tobacco, peppermint, vinegar, coffee, lemon, perfume and so forth, is inhaled and the patient asked to identify it. No pungent substance may be used because the subject can recognize its presence through the irritating effect on the fibers of the trigeminal nerve in the nasal mucosa. The patient's failure to identify an odor he has never previously experienced is no indication of anosmia. Elsberg and his co-workers have devised a quantitative olfactory test for the critical study of this function (see Tests for Smell, p. 528).

#### TRIGEMINAL NERVE

This nerve transmits sensory impulses from the face, eye, nasal and oral mucosa, teeth and tongue (common sensation). Its motor branch innervates the muscles of mastication. Vital sensations (touch, pain, temperature) of one-half the face and anterior half of the scalp are tested with a wisp of cotton, pin-point and warm and cool objects. (The part of the face over the angle of the jaw is supplied by the second cervical spinal nerve.)

The cornea is tested for sensation and the palpebral reflex by touching the cornea lightly with a pointed wisp of cotton or a hair stimulator, approached from the side of the line of vision; the reflex response is a prompt blink. The cornea should be touched just within the corneoscleral junction.

The *lacrimal reflex* consists in a flow of tears after the introduction of a cotton-tipped applicator in the nasal cavity.

Normal function of the motor branch permits depression of the mandible on the midline. If the pterygoid muscles are paralyzed, the mandible will deviate to the affected side when the mouth is opened widely. Fullness and contraction of the masseter and temporal muscles are tested with palpating fingers while the patient chews.

#### FACIAL NERVE

The facial nerve supplies motor innervation to the muscles of emotional expression and some of the articulatory muscles. The two halves of the face are compared for symmetry and voluntary and mimetic movements. The patient is asked to wrinkle the forehead, frown, shut the eyes tightly and wink repeatedly, retract the corners of the mouth, puff out the cheeks, pucker the lips,

\* There are twelve pairs of cranial nerves: olfactory, optic, oculomotor, trochlear, trigeminal, abducent, facial, auditory, glossopharyngeal, vagus, spinal accessory, hypoglossal. The functions of optic and ocular nerves are included in Section 12; of the auditory nerve, in Section 13.

screw up the nose, and whistle. To ask a patient to smile is not a reliable test for mimetic innervation; it must be provoked by an appropriate emotional stimulus.

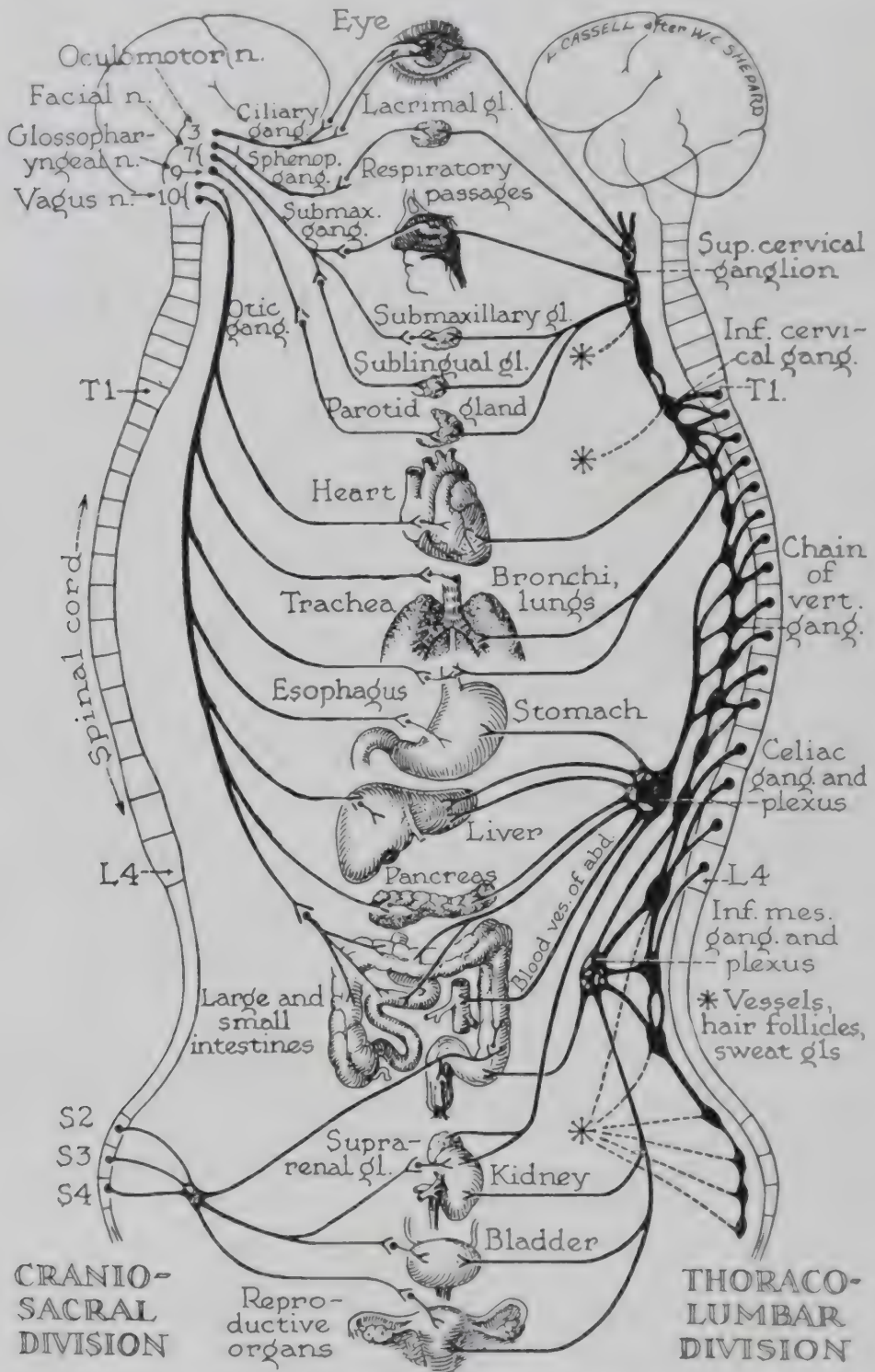


Fig. 73. Diagram of the autonomic nervous system. (Millard and King: Human Anatomy and Physiology.)

### CHORDA TYMPANI NERVE

The chorda tympani nerve, supplying taste to the anterior two-thirds of the tongue, in part of its course runs with the seventh nerve. Its function is

ted by the application of a solution or suspension of sweet, sour and salty substances applied successively after wiping off the preceding application. The tongue is to remain protruded throughout the test, and the patient indicates his gustatory perception by pointing to the name of the respective substance on a card.

### GLOSSOPHARYNGEAL NERVE

This nerve supplies motor innervation to the superior pharyngeal constrictor. Unilateral affection is difficult to test. The chief loss of function which can

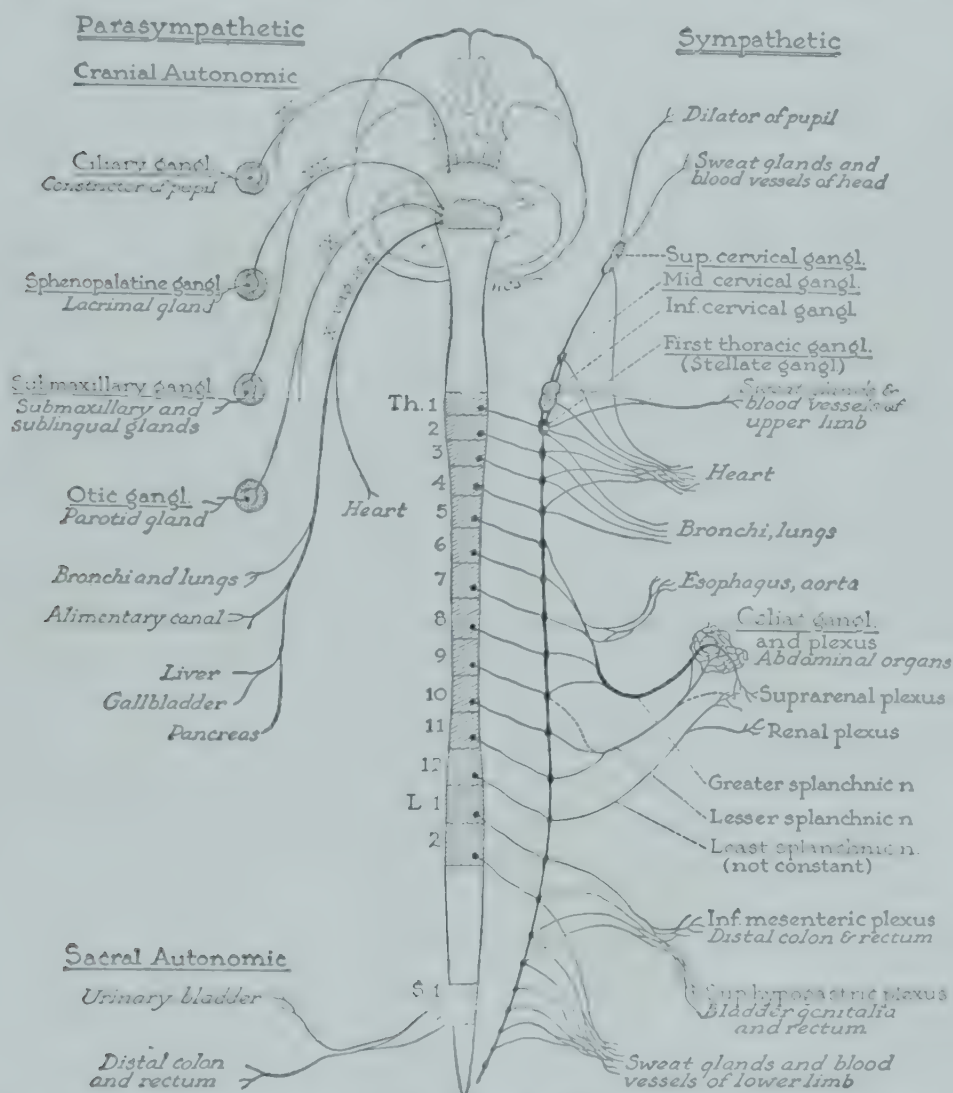


Fig. 74. Scheme of autonomic system. (Jones and Shepard: Manual of Surgical Anatomy.)

tested is taste on the posterior third of the tongue, tested for perception of the bitter quality of a substance such as quinine.

### VAGUS NERVE

The routine neurologic examination for involvement of this nerve is concerned with unilateral palatal and vocal chord mobility. Under normal conditions the soft palate is symmetrically arched, with elevation and retraction of the uvula in the midline. Unilateral paralysis is recognized by the ipsilateral

half of the soft palate remaining motionless while the normal side is elevated and the uvula is pulled to the good side. Unilateral vocal chord paralysis is recognized by hoarseness, and with mirroscopy the vocal chord on the affected side remains in the cadaveric position. The influence of unilateral vagus nerve paralysis on the vegetative functions such as pulse, respiration and so on may

TABLE 179  
POSITION OF NERVE ROOTS RELATIVE TO THE VERTEBRAL COLUMN\*  
(Gray, 1942)<sup>1</sup>

<i>Level of Body of</i>	<i>Number of Nerve</i>	<i>Level of Tip of Spine of</i>
C1.....	C1	
	C2	
C2.....	C3	C1
C3.....	C4	C2
C4.....	C5	C3
C5.....	C6	C4
C6.....	C7	C5
	C8	C6
C7.....	T1	C7
T1.....	T2	T1
T2.....	T3	
T3.....	T4	T2
T4.....	T5	T3
T5.....	T6	T4
T6.....	T7	T5
T7.....	T8	T6
T8.....	T9	T7
T9.....	T10	T8
T10.....	T11	T9
	T12	T10
T11.....	L1	T11
	L2	
T12.....	L3	
	L4	T12
	L5	
	S1	
L1.....	S2	
	S3	
	S4	L1
	S5	
	C1	
L2.....		

\* This table is used as follows: e.g., at what level do the tenth thoracic nerve roots lie? Answer: at the body of the ninth thoracic or tip of the eighth thoracic vertebra.

be identified only in the acute phase of the lesion. The insulin test for vagus fibers after vagometry is given on page 238.

SPINAL ACCESSORY NERVE

Involvement here is indicated by atrophy and paralysis of the sternocleidomastoid muscle and upper half of the trapezius muscle. Testing is made by bringing into play the respective physiologic motor functions against resistance.

## HYPOGLOSSAL NERVE

This nerve controls mobility of half of the tongue. When the nerve is diseased, half of the tongue is atrophied and fibrillary twitchings may be observed; tongue, when protruded, deviates to the affected side.

## MOTOR SYSTEM

From both the anatomic and physiological points of view it is usual to consider the motor system as comprising four components: (a) the upper motor (pyramidal) neurone, (b) an extrapyramidal system of neurones, (c) the cerebellar system and (d) the lower motor neurone. In the spinal cord, reflex mechanisms subserve a variety of movements, locomotor and defensive. The maintenance of posture necessary for these movements to be effective is a function of reflex arcs that have their centers in the pons and medulla. Other reflex mechanisms centered in the midbrain are essential to stance and movements. Superadded over this basic mechanism are the upper motor neurone (pyramidal system) and the cerebellar system. The former is regarded as the sole channel by which the subordinate motor mechanisms are activated in the performance of voluntary motor acts; the cerebellum has its role in the harmonious combination of movement and posture.

The skeletal musculature is examined to determine power, muscle bulk and tone. Body lines and muscle configuration are compared visually for symmetry on the two sides of respective muscle masses. Tone is tested by palpation and passive manipulation of the limbs, comparing respective parts. Voluntary power is determined by resistance, the hand-grips by squeezing the examiner's hands against a manual dynamometer (this, however, has no fixed normal, but is an arbitrary value in comparing the two grips with that of the examiner, and allowance made for the body build of the patient, his age, sex and handedness). Muscle atrophy is recognized by relative loss of muscle bulk or volume, and it is to be noted whether it is limited to one muscle, a group of muscles, an entire extremity, half the body, or is universal.

Normal function should be synergic with smooth, coordinated movements. The *finger-to-nose test* will illustrate this: With eyes closed or open, a fingertip should approach the tip of the nose with a smooth swing of the arm at the shoulder level and touch the nose accurately without tremor.

The same is done with the *finger-to-finger test*, the patient's index finger touching the examiner's finger repeatedly.

The *pronation-supination test* with the hands (diadokokinesia) is done by rapidly alternating the movement with arms extended in midair or patting the back and palm of the hand alternately on the knee. An even amplitude should be observed with smoothness of movement.

In the *heel-to-knee test* the patient lies supine and places one heel on the opposite kneecap with normal synergy of movement and accuracy of placement. The heel may then be moved smoothly down along the shinbone to the ankle to show coordination of placement and motion.

Under normal conditions a person is able to walk a straight line, placing heel to toe alternately without faltering or loss of balance (*heel-to-toe test*).

The trunk is tested by standing with the feet together and eyes closed (Romberg), at which time there should be no sway of the body. Walking around a chair or other object, clockwise and counter-clockwise, without deviation away from the object or knocking it, is a normal function. With the arms folded across the chest one should be able to assume the sitting position from the supine without the feet simultaneously rising.

## REFLEXES

**PUPILLARY REFLEX.** Stimulation of the retina by light produces a contraction of the pupil.

**CORNEAL OR LID REFLEX.** Irritation of the cornea causes a closing of the eyelids.

**PHARYNGEAL OR GAG REFLEX.** Touching the back of the pharynx produces a contraction of the constrictor muscles of the pharynx.

**MANDIBULAR REFLEX.** If a reflex hammer is tapped on an examiner's thumb which has been placed on the center of the mandible depressed halfway, an upward jerk of the jaw may be obtained. It may be occasionally elicited in mild degree as part of functional hyperreflexia. Marked exaggeration occurs in pyramidal tract lesions of the brain.

**BICEPS REFLEX.** The examiner's thumb is placed on the biceps tendon at the elbow and is tapped with the reflex hammer; the forearm flexes. This is a variable reflex and may be difficult to obtain in normal persons with low reflex activity. It may require reinforcement by putting the biceps muscle on a little tension through change of position of the arm held by the examiner.

**BRACHIORADIAL REFLEX.** With the forearm in midsupination-pronation position and supported by the examiner, the lower end of the radius is tapped with a reflex hammer. The reaction is a flexion of forearm, hand and fingers.

**TRICEPS REFLEX.** The patient's elbow with the forearm semiflexed is supported in the examiner's hand. The triceps tendon is tapped with the hammer, resulting in extension of the forearm.

**PATELLAR REFLEX.** This may be elicited in several ways: (1) The patient may be seated with the feet on the floor and the examiner's hand on the quadriceps muscle. The patellar tendon is then tapped, causing reflex extension of the leg. (2) The leg may be crossed over the opposite knee, and the foot kicks out with extension of the leg on patellar tendon tapping. (3) In a bed-patient, both knees may be supported by the examiner's forearm placed under them. The patellar tendons are tapped with quantitative variation of stimuli, and comparison is made of the strength of the extensor kick of the leg.

**ACHILLES REFLEX.** The tendo achillis is tapped with resultant plantar extension of the foot. The patient may kneel on a chair with feet relaxed in space, or, if he is in bed, the leg may be supported while the examiner holds the foot slightly dorsally flexed as the tendon is tapped.

**PLANTAR REFLEX.** The foot is stroked with a semiblunt object along the outer edge and forepart of the sole. Watch for reflex movement of the great toe in flexion.

**ABDOMINAL REFLEX.** The abdominal reflexes are examined by lightly stroking the skin of the abdomen over its four quadrants and watching for the reflex movement of the umbilicus toward the stimulated side. In elderly persons and those with obese or flabby abdomens, these reflexes are usually not obtainable.

**CREMASTERIC REFLEX.** This consists in retraction or elevation of the testicle when the skin of the upper inner thigh is lightly stroked. This and the abdominal reflex vary in intensity according to the natural reflex excitability of the individual or his hypervigilance at the time of the test.

**SCAPULOHUMERAL REFLEX.** A tap on the vertebral border of the scapula causes, in some normal persons, a sharp retraction of the scapula and arm on the stimulated side.

**BICEPS FEMORIS REFLEX.** This reflex is elicited by tapping the examiner's thumb placed on the respective hamstring tendon while the patient lies on his side with the examined limb uppermost and flexed at the hip and knee. The reflex is a short flexion movement of the leg.

**GLUTEAL REFLEX.** This is a contraction of the gluteal muscles when the skin of the buttock is stroked.

**SCAPULAR REFLEX.** This reflex, obtained by stroking the skin between the scapulae, produces a contraction of the scapular muscles.

## SENSORY NERVES

The modes of sensibility may be divided into superficial (cutaneous) and deep. Of cutaneous sensibilities there are four primary modes: light touch, cold, warmth and pain. Deep sensibility includes painless and painful pressure, postural sensibility and vibration sense. Each mode of cutaneous and, to a lesser degree, of deep (painless and painful pressure) sensibility carries a local sign, i. e., the appropriate sensation is not only evoked, but is also localized, and when two contacts are separated in space, two distinct stimuli can be perceived. This is known as two-point discrimination. Postural sensibility depends upon sensory end organs located in tendons, muscles and joints. By means of stimuli exciting these end organs the subject is able to ascertain the position of the limb and its several parts in space, and to appreciate the degree of their movements.

Touch, pain, heat, cold, position and vibration senses are normally present in all persons. The patient's state of mind, his emotions, and the surface temperature of his body influence the results of sensory testing. Apprehension and fatigue interfere with reliable results.

**TOUCH.** Touch is tested by the application of a light contact stimulus of any sort, provided the element of pressure is eliminated. A wisp of cotton on an applicator, a camel's hair brush, the point of a handkerchief or even the examiner's finger may be used.

**PAIN.** A pin prick tests the pain sense; the patient is asked to differentiate between sharp and dull pain. Some people are more sensitive than others to a sharp stimulus, and one may speak of *hyperalgesia* (increased sensitivity of a part) or *hypoalgesia* (diminished sensitivity). (For pain points of skin, see p. 471.)

**HEAT AND COLD.** Temperature contact may be made with two test tubes, one containing hot water and the other cracked ice, but lesser differences are

to be tested by the use of warm and cool objects rather than hot and cold. (For cold and warm points of the skin, see p. 470.)

**VIBRATION.** Vibratory perception is tested with the vibrations of a C-12 tuning-fork, the base of which is applied to the bony prominences of the skeleton—usually the ankle, shin, knee, iliac crests, spinous processes, sacrum, elbow and wrists. The clarity of the perception and its duration are compared with the examiner's normal. In persons past middle life this sensory perception may be physiologically diminished or lost.

**POSITION AND PASSIVE MOTION (GNOSTIC SENSIBILITIES).** The examiner tests position sense by moving the toes and fingers held by the sides, and the patient should indicate the moment he appreciates the beginning of motion and in what direction as well as the position the digit is held. *Two-point discrimination* on the skin is tested with a calibrated compass. Although there are no normal standards for clinical use, one makes use of the fact that respective parts of the body usually are equally acute for recognition of duality of contact. A normal person with eyes closed can indicate with his finger where his skin was touched—*spot localization*. The ability to recognize, without looking, figures, numbers and letters traced on various parts of the body is called *graphesthesia*. Stereognostic perception is the ability to recognize, without the aid of vision, the size, shape and identity of an object held in the hand. The recognition of differences in texture and weight of objects held in the hand without the use of vision is also a normal gnostic perception.

## ELECTRICAL REACTIONS OF MUSCLES

Faradic and galvanic currents are used to test the quantitative reactivity of muscles, and the galvanic current to detect qualitative or modal changes. A large indifferent electrode is placed on the chest, the interscapular region or the sacrum, while a small active electrode makes contact with the skin, first over the course of the peripheral nerve being examined and then at the proximal end of the muscle where its nerve enters, the so-called motor point. A normal nerve transmits a faradic and galvanic impulse with a resultant sharp, short contraction of the muscles it supplies. Individual muscles respond similarly by stimulation of their respective motor points. A muscle is compared with its mate of the other limb to determine increased or decreased excitability.

Comparative values may be roughly made with the faradic current by the distance the secondary coil has to be moved over the primary core to reach the threshold of excitability for production of the contraction.

The galvanic excitability is determined by the galvanometer in circuit. With the galvanic current there is a difference in polar reactions; normally the cathodal closing contraction is stronger than the anodal closing contraction. Contractions produced by opening the circuit are not used in routine electrical reaction tests.

**MOTOR POINT.** The point of maximum response to a given strength of current in a muscle is that area which corresponds to the motor nerve entering the muscle. This area, called the motor point, is located at about the middle of

belly of the muscle. All muscles, with the exception of those hidden by other muscles, have accessible motor points for testing.

TABLE 180  
EVALUATION OF ELECTRICAL REACTIONS IN MOTOR MUSCLE TESTS  
(Groff, 1945)<sup>2</sup>

	<i>Faradic</i>	<i>Galvanic</i>	<i>Polarity*</i>	<i>Longitudinal Reaction</i>
Reaction: Normal	+++	+++	CCC > ACC	
Moderate RD*	++	++	CCC = ACC	
Complete RD	0	0	0	
Reaction: Normal	+++	+++	CCC > ACC	0
Moderate RD	++	Slow	CCC = ACC	+ or -
Severe RD	0	Feeble	ACC > CCC	+
Complete RD	0	0	0	0

\* RD = reaction to degeneration. CCC = cathodal closing contraction. ACC = anodal closing contraction.

## INFANTILE NERVOUS SYSTEM

The anatomic development of the nervous system is far from complete at birth. There is a close parallelism between the myelination of the nervous system and the development of its physiologic activities, and it may be assumed that complete functional activity cannot appear before anatomic maturity is attained. It seems to be generally assumed that the cerebrum or, perhaps more accurately, the cerebral cortex exerts no influence upon the segmental apparatus in the newborn. The cranial and spinal segments and the special sense organs are, however, capable of functional activity, although probably not of complete function. As for motor reactions, the lack of cerebral function in the newborn is expressed in two ways: (a) absence of true "volitional activity," and (b) lack of inhibition of the segmental apparatus. The motor reactions of the newborn are entirely reflex. A number of reactions are elicited under normal conditions during only the first few months of life. Volitional activity slowly develops, and many of the reflex reactions are gradually inhibited and obscured, being elicited henceforth only in pathologic states.

**PLANTAR REFLEX.** The response is variable in the first few months. Both extension and flexion of the toes occur, but extension predominates; the movement of extension is not identical with the true Babinski reflex. The normal response of flexion slowly becomes established between the first and second years. No information of clinical importance can be obtained from a study of the plantar reflex before the end of the second year.

**ABDOMINAL REFLEX.** Abdominal reflexes may be elicited in about one-third of all the newborn. The reflex obtained at this age is a rather diffuse reaction, often involving the extremities, and is probably essentially different from the adult response. Sometime between the sixth month and the end of the first year the true abdominal response should appear.

**SUCKING REFLEX.** Stimulation of the lips or almost any part of the face will produce in the newborn infant opening of the lips and movements such as are made in sucking. This response should disappear under normal conditions by the end of the first year.

**GRASPING REFLEX.** This reflex is almost constantly demonstrable in the first few weeks of extra-uterine life and disappears between the second and the fourth month. The reflex is elicited by placing the examiner's finger in the infant's palm; the child's fingers then close tightly, and any attempt at withdrawal of the finger causes the grip to tighten. If the child is induced to grasp a rod with both hands, it is often possible to suspend the infant in the air for several seconds before the grasp relaxes.

**MORO REFLEX.** This reflex is provoked by almost any sudden stimulus such as a loud noise, quick passive movement or a sudden tap upon the abdomen. The usual stimulus used is a hard blow delivered with either hand upon the couch close to the infant's body, the child lying on its back. The reaction consists in adduction and extension of all four extremities, often followed by abduction and flexion, especially of the arms. This reflex is present under normal conditions during the first three months of life and usually disappears before the fifth month. The tendon jerks are present from birth in normal children.

**SENSIBILITY.** Sensibility is present, but probably not acute. Painful stimuli cause crying and struggling. The infant is also insensitive to changes of temperature, but will cry when cold. Tactile stimuli cause active responses, especially about the eyelids, nose and lips. The special sense organs are active. A bright light thrown into the eyes causes firm closure of the lids and contraction of the pupils. The child may follow the light with the eyes, but does not fix accurately. Hearing is much reduced for the first day or more, perhaps because of lack of air in the middle ear. Subsequently, the infant will respond to loud noises by blinking of the eyelids and movements of the extremities as in the Moro reflex. The sense of smell is probably absent or defective. In the second month crying is accompanied by tears and an expression of distress. The child may smile when pleased. Visual fixation is more accurate, and ocular movements are concomitant. The head and eyes turn toward sound. In the fourth month the child should begin to hold up the head and may even try to sit up. In the sixth month the child should sit up for several minutes and usually is beginning to crawl. He may try to stand in the eighth month, and some precocious infants even take a few steps. In the tenth month the child sits up firmly and stands a short time without assistance. Many children try to walk. At one year the child stands well and should take a few steps without assistance. At the eighteenth month he should walk well and at the second year should run about actively.

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## Chapter 35

### ENCEPHALOGRAM

ENCEPHALOGRAPHY permits visualization of the cerebral structures on the roentgenogram after the withdrawal of fluid from the cerebrospinal spaces and its replacement by air. This can be accomplished by either the lumbar or cisternal route.

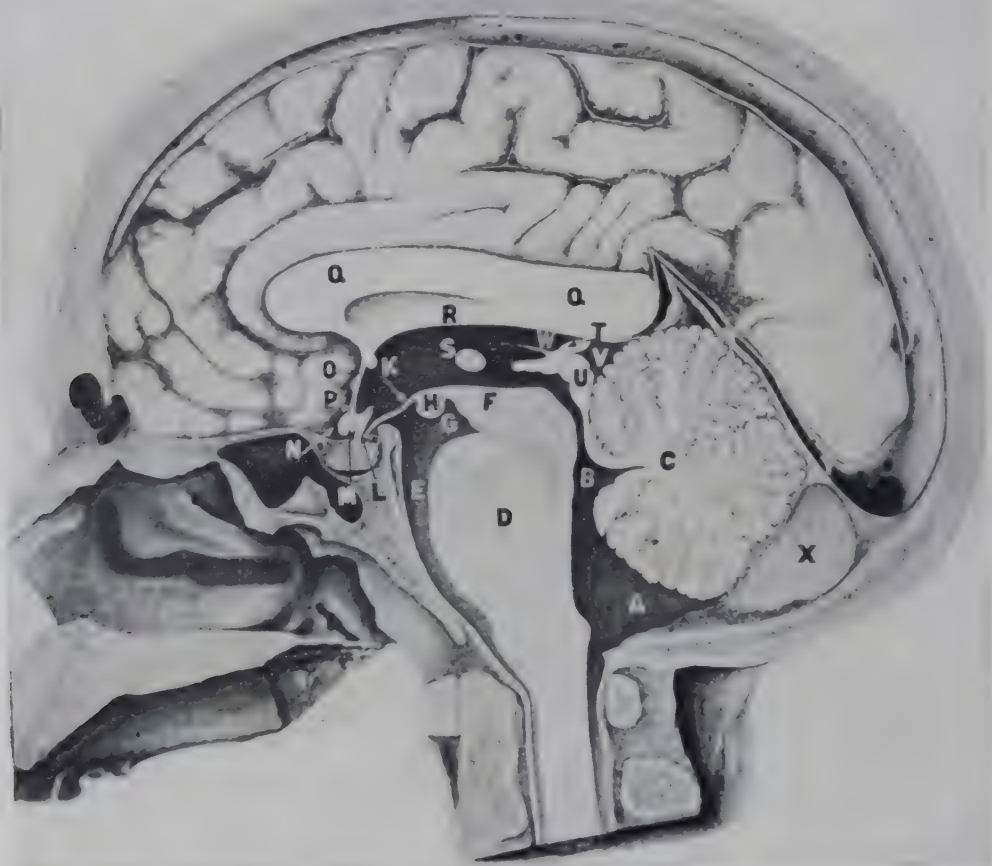


Fig. 75. Sagittal section of the head, showing an injection mass in the subarachnoid space and ventricles, outlining particularly the various cisterns. A, Cisterna magna; B, fourth ventricle; C, cerebellum; D, pons; E, cisterna pontis; F, cerebral peduncles; G, cisterna interpeduncularis; H, corpora mammillaria; K, tuber cinereum; L, infundibulum; M, optic chiasm; N, cisterna chiasmatis; O, lamina terminalis; P, cisterna cinerea; Q, corpus callosum; R, fornix; S, third ventricle; T, pineal body; U, colliculi; V, cisterna ambiens; W, suprapineal recess; X, falx cerebelli; Y, straight sinus in tentorium. It should be noted that the force of injection has evidently overfilled the cisterna magna and has thus displaced the structures above it too far dorsally. (Davidoff, L. M., and Dyke, C. G.: *The Normal Encephalogram*, Lea & Febiger.)

Ventriculography permits the roentgen demonstration of the ventricles after the removal of the fluid and its replacement by air. This is accomplished

the proper placing of burr holes in the calvarium and then tapping the ventricles by passing a needle through the substance of the brain into the ventricles.

# THE LATERAL VENTRICLES

Each of the lateral ventricles is divided into a body, and an anterior, superior and inferior horn (see Figs. 77 and 78).

**BODY** The body extends from the interventricular foramen to the splenium of the corpus callosum. The posterior part of the body diverges from the midline at 35 degrees laterally and 60 degrees vertically. The length is about 5 cm. and the height about 1.2 cm. (somewhat greater at each end). The outermost measurements in the postero-anterior view vary between 3.5 and 4.5 (average about 4 cm.) (Figs. 78 and 79).



Fig. 76. Encephalogram showing a normal measurement (3.7 cm.) from the floor of the lateral ventricle to the dorsum sellae (arrows point to these structures). (Davidoff, L. M., and Davidoff, C. G.: The Normal Encephalogram, Lea & Febiger.)

**ANTERIOR HORN.** This part of the ventricle extends anterior to the interventricular foramen. In the anteroposterior position the narrow strip between the lateral ventricles represents the *septa pellucida*. This shadow is usually 2 to 3 mm. wide. The anterior horn is approximately 2 cm. in height, 1 cm. in width and 3 cm. in length (Fig. 79).

**POSTERIOR HORNS (OCCIPITAL).** These are extensions of the body into the occipital lobes. In the postero-anterior view they are disklike and are about 1 cm. from each other. The size and shape are variable.

**INFERIOR HORNS (TEMPORAL).** These are anteroventral projections of the body. The distance between the inferior horns in the postero-anterior view is about 10 cm. (average, 9 cm.). They are about 5 cm. long (Figs. 78 and 79).

## MEASUREMENTS OF THE VENTRICLES IN THE POSTERO-ANTERIOR VIEW

The height between the dorsa of the septa pellucida and the line between the tops of the body varies from 0.3 to 0.7 cm. (average, 0.5 cm.) (Fig. 77).

The ratio of the greatest transverse diameter of the anterior horn to the greatest transverse diameter of the skull is usually 0.20 to 0.25 cm. The normal range is 0.16 to 0.29 cm.

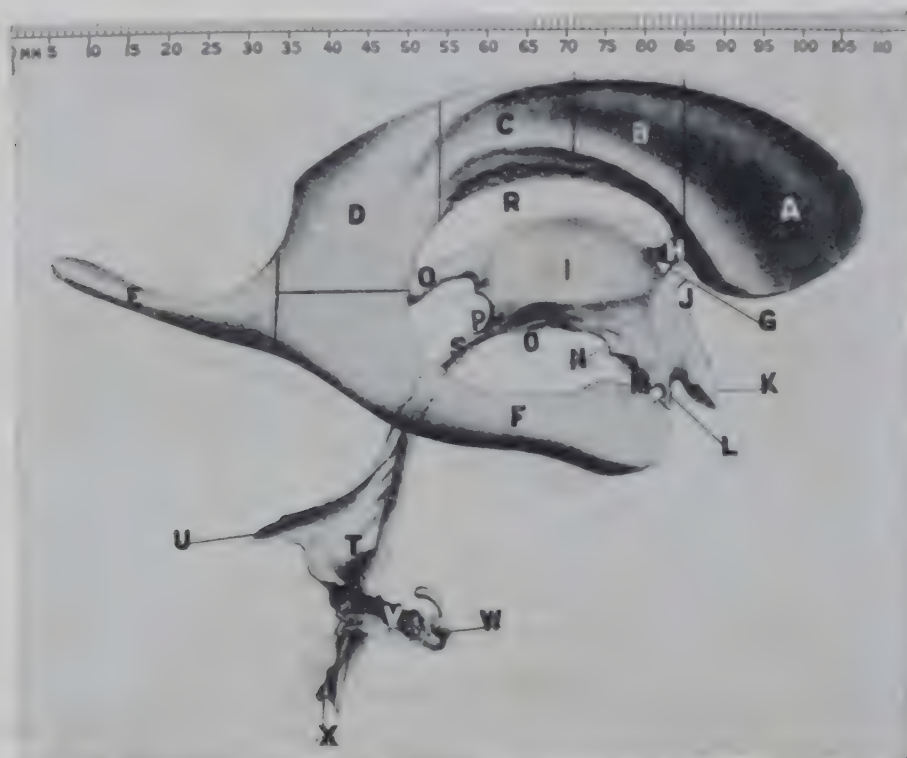


Fig. 77. Cast of normal ventricular system, right lateral view. A, Anterior horn; B, anterior third of body; C, middle third of body; D, posterior third of body; E, occipital horn; F, temporal horn; G, foramen of Monro; H, interventricular foramina; I, third ventricle; J, anterior commissure; K, optic recess; L, infundibulum; M, tuber cinereum; N, corpora mammillaria; O, cerebral peduncle and tegumentum; P, posterior commissure; Q, suprapineal recess; R, fornix, ependyma and choroid plexus of third ventricle; S, aqueduct of Sylvius; T, fourth ventricle; U, superior posterior recess of fourth ventricle; V, lateral recess of fourth ventricle; W, foramina of Luschka; X, foramen of Magendie. (Davidoff, L. M., and Dyke, C. G.: *The Normal Encephalogram*, Lea & Febiger.)

## THIRD VENTRICLE

The width of the third ventricle varies from 2 to 8 mm. The height averages 2 cm. Because of its irregular shape the size in the lateral view is difficult to determine. The diagonal distance from the foramen of Monro to the aqueduct of Sylvius averages 2.6 cm.

## AQUEDUCT OF SYLVIIUS

The aqueduct of Sylvius is 1.5 cm. long and 0.1 to 0.2 cm. wide.

## FOURTH VENTRICLE

The size of the fourth ventricle in the lateral view in the cephalic caudal angle is 4 cm. The distance from the fastigium to the floor is about 1.6 cm.

width of the sulci varies from 1 to 3 mm. The thickness of the corpus sum in the postero-anterior view varies from 0.3 to 1.2 cm. when measured the midline.

### CISTERNA MAGNA

In the lateral view the greatest depth of this cistern varies from 5 mm. cm.

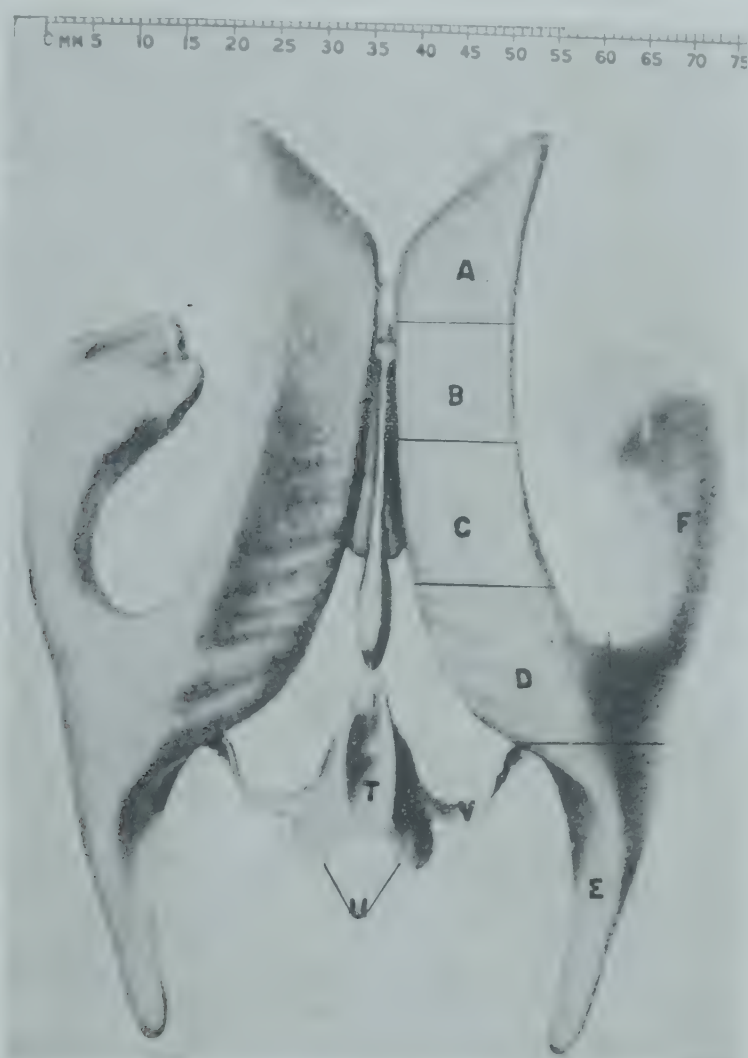


Fig. 78. Cast of normal ventricular system, dorsal view. A, Anterior horn; B, anterior part of body; C, middle third of body; D, posterior third of body; E, occipital horn; F, temporal horn; T, fourth ventricle; V, lateral recess of fourth ventricle; U, superior posterior recess of fourth ventricle. Davidoff, L. M., and Dyke, C. G.: The Normal Encephalogram, Lea & Febiger.

### CISTERNA PONTIS

The depth of this cistern from the dorsum to the midpons is about 5 mm., 12 mm. at the cephalic part of the pons. The pons measures about 2.8 cm. in the cisterna pontis to the anterior part of the fourth ventricle when seen in the lateral encephalogram.<sup>2</sup>

### CISTERNA AMBIENS

Near the interpeduncularis this cistern measures, ventrally, about 4 mm. width, and dorsally about 5 to 7 mm.

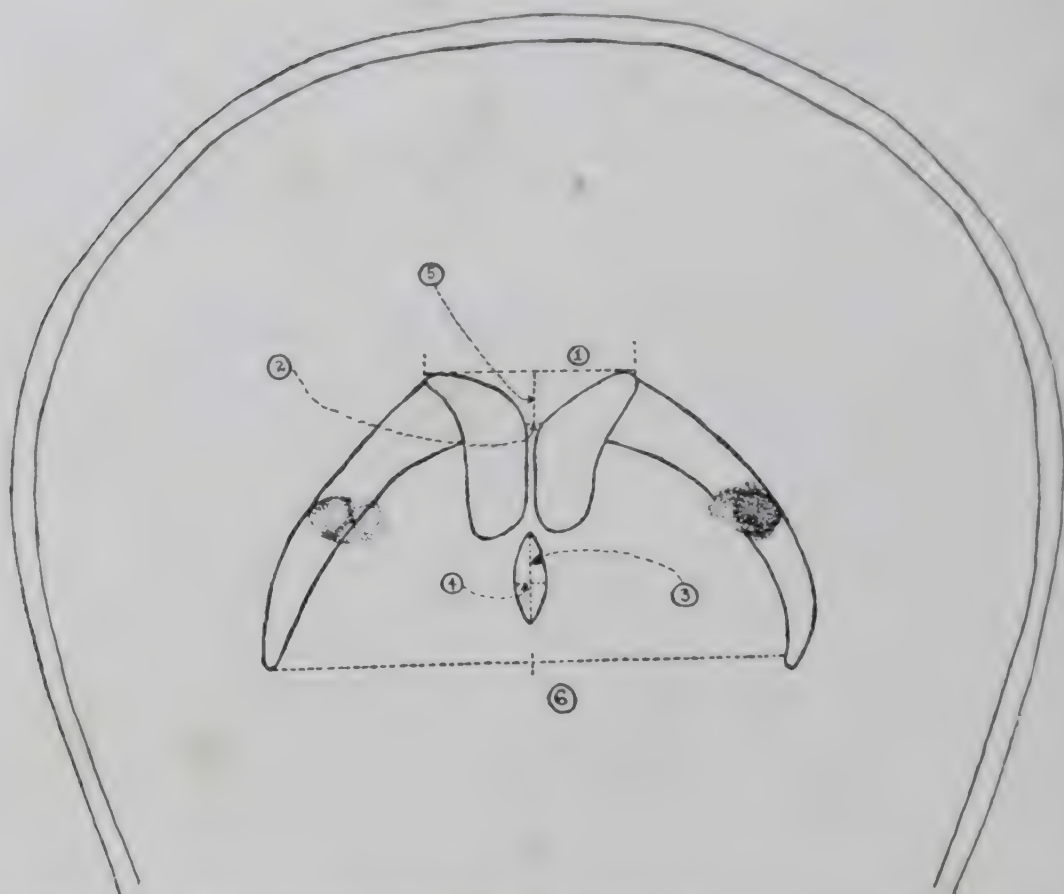


Fig. 79. Sketch of the ventricular system, showing how measurements were taken: 1 = 3.5 to 4.5 cm.; 2 = 2 to 3 mm.; 3 = 2 cm.; 4 = 2 to 8 mm.; 5 = 0.3 to 0.7 cm.; 6 = 7.5 to 10 cm. These measurements were made in 150 encephalograms in which the size of the ventricles appeared to correspond to the accepted size given for the normal in standard books on anatomy. (Davidoff, L. M., and Dyke, C. G.: *The Normal Encephalogram*, Lea & Febiger.)

## THE COMMISSURES

**ANTERIOR COMMISSURE.** In the lateral encephalogram this commissure is oval and measures approximately 5 by 3 mm. The intermediate mass measures 7 to 10 mm. in diameter.

**POSTERIOR COMMISSURE.** This commissure measures about 3 mm. in diameter.

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## Chapter 36

### ELECTROENCEPHALOGRAM

SIGNIFICANT features of the pattern in an electroencephalographic tracing (G) can be described in terms of a small number of characteristic configurations. These are considered normal if they appear preponderantly in records of clinically normal persons when large groups of records from both normal and abnormal subjects are examined. Whether or not a given record as a whole is to be considered normal depends on the interpretation of the various configurations plus an examination of their relation to each other.

An attempt to describe the patterns of electroencephalographic activity that may be considered "normal" immediately reveals the difficulty of defining this term accurately. For example, a given record may be reported as "essentially normal," although traces can be found of a configuration usually considered abnormal. Such a situation would arise if the remainder of the record were composed of "normal" configurations which provide no evidence to substantiate the suggestion of abnormality. It is, therefore, more accurate to speak of the probability that a given configuration would or would not be seen in the records from a large group of normal persons, than to label any configuration as definitely normal or abnormal.\*

The commonly accepted procedure for obtaining reliable records on normal persons is to record the potential changes between various points on the scalp and an electrode fastened to the ear which serves as an indifferent electrode, although Williams and Reynell<sup>16</sup> have shown that this is only a close approximation. Jasper<sup>8</sup> has also used a basal lead inserted through the nose as a diffuse lead for studying diencephalic and midbrain structures.†

Owing to various factors affecting the pattern which will be discussed later, the routine procedure<sup>2</sup> is to take the record with the patient in an alert condition, the eyes closed, the body relaxed, and with no disturbing sounds. Blood sugar must be within normal limits at the time of taking the record, and the patient must not be receiving any medication. Artifacts due to muscle activity, physical movement and sweating, and errors of instrumentation, such as poor contact of electrodes, all described by Gibbs and Gibbs,<sup>5</sup> must be carefully avoided.

#### ALPHA RHYTHM

The alpha rhythm is a pattern of roughly sinusoidal waves with a frequency between 8 and 12 per second in normal adults (see Fig. 80, A). The mean alpha frequency of 1620 persons studied by McFarland and Franzen<sup>12</sup> was

\* The general subject of electrical activity of the brain has been reviewed by Lennox and Lennox.<sup>1001</sup>

† For a review of technique, evaluation and interpretation, see Gibbs and Gibbs<sup>5</sup> and Jasper.<sup>8</sup>

9.94 cycles per second, with a standard deviation of 0.96 cycles per second. Shagross<sup>1a</sup> gives the value of 10.16 cycles per second with a standard deviation of 0.81 for a group of 1100 adult aircrew candidates. Forbes and Davis<sup>8</sup> found the fluctuation of the alpha frequency of a given subject to vary in normal records from a fraction of a cycle per second to as high as 2 cycles per second. Loomis, Harvey and Hobart<sup>11</sup> showed random variations of alpha frequency in a given person of about 1 cycle per second in forty-two measurements made over the course of seven months. They also showed a decrease of frequency in records taken after sleep when compared with those taken before. Jasper and Andrews,<sup>9</sup> in their study of the electroencephalogram of normal adults, found that the alpha frequency could be accelerated by stimulation of the subject with bright light. When the dominant frequency of a record no longer falls within the alpha range, the probability that this represents normal activity falls off sharply as the frequency decreases. Thus, while records with a mean frequency between  $7\frac{1}{2}$  and  $8\frac{1}{2}$  cycles per second may be either normal or abnormal, records with a mean frequency below  $7\frac{1}{2}$  per second are seldom obtained from normal persons. The average value of the persistence of the alpha rhythm from two occipital areas was 57.7 per cent with a standard deviation of 27.6 per cent in 1692 subjects studied by McFarland and Franzen.<sup>12</sup> Brazier and Finesinger<sup>1a</sup> studied the alpha rhythm in 500 normal adults and found a mean persistence of 61 per cent.

**DISTRIBUTION.** In normal adults the alpha rhythm is symmetrically distributed over the two hemispheres so that it can be seen with nearly equal persistence (measured as percentage of time present) on the records from homologous areas of the two hemispheres. Strauss, Liberson and Meltzer<sup>15</sup> found that the records from normal persons rarely showed more than 30 per cent difference in the persistence of the alpha activity from homologous areas of the occipital lobes. Other observers feel that a 15 per cent difference is probably significant. Rubin<sup>13</sup> described a secondary center of alpha activity in the frontal area, but Adrian and Yamagiwa<sup>1</sup> described this as a pseudofocus caused by transmitted activity from a single source in the occiput.

### FAST WAVES (BETA RHYTHM)

The significance of a dominant frequency faster than the alpha range is less well defined than that of the slow waves. Finley<sup>3</sup> reports that in 300 normal control subjects fast activity was present in only 3 to 8 per cent of the records. When present, it was commonly in the frontal area, while the most usual frequency was 25 per second. Jasper and Andrews<sup>9</sup> and Gibbs and Gibbs<sup>4</sup> report a gradual increase in the amount of fast activity above 12 per second in the records from normal adults with increasing age (see Fig. 80, B).

### SLOW WAVES (DELTA WAVES)

When waves appear on the record with a mean frequency lower than the alpha limit of 8 per second, the probability that they represent some form of abnormal activity rises rapidly as the frequency decreases, no matter whether they appear singly, in groups, or in a continuous train. This statement is true

matter where the slow waves arise, but it must be remembered that this applies only to adults fully awake. It is possible to see "abnormal" slow waves in the record from a symptom-free person when certain factors in his physical

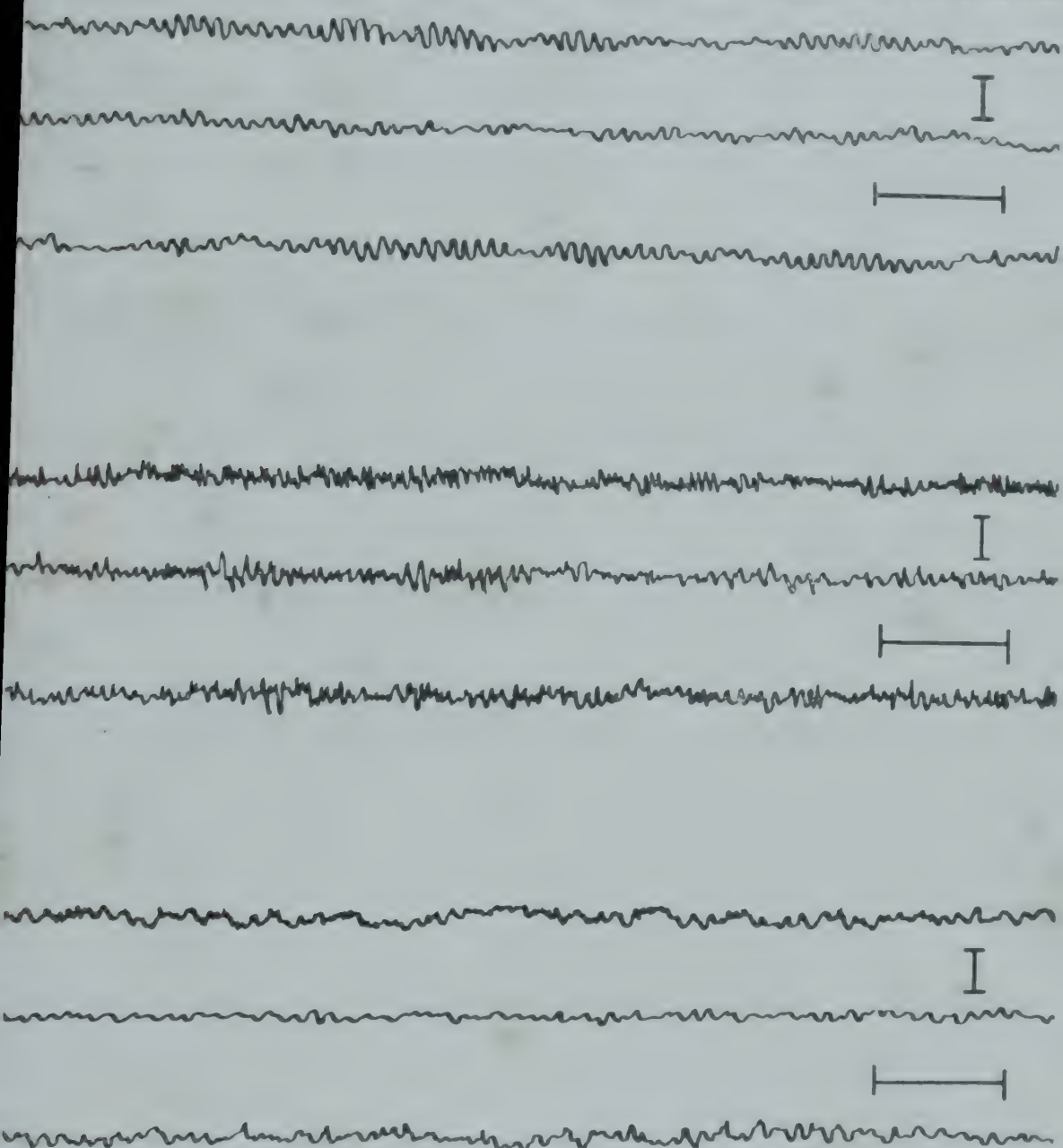


Fig. 80. Typical normal patterns, showing alpha rhythm (all records from occiput). Vertical bar represents 100 microvolts deflection. Horizontal bar equals 1 second of recording time. Alpha waves of nearly sinusoidal form with average persistence of 100 per cent. Top line, monopolar, left ear to left occiput; middle line, bipolar, left occiput to right occiput; lower line, monopolar, right occiput to right ear. *B*, Alpha waves with persistence of 30 per cent overlaid with fast (beta) waves. Electrodes connected as in *A*. *C*, Alpha waves with persistence of 80 per cent mixed with considerable irregularity. Electrodes connected as in *A*. (From records taken by Scott.)

environment are altered, such as lowering of blood sugar, or oxygen tension. A record which shows slow waves under such circumstances will be considered as deviating from the normal even though the slow waves may be considered artificially induced. No record can properly be called normal which contains

recognizable slow waves unless they are smaller than 20 to 25 microvolts and have a persistence of less than 10 to 15 per cent, in which event their interpretation is uncertain.<sup>\*</sup> Brazier and Finesinger<sup>1a</sup> in their group of 500 normal adults found waves 7 to 7.5 cycles per second from the occiput in 125 cases, but in only four cases were they present more than 5 per cent of the time. In the same study waves as slow as 6 cycles per second were obtained from the occiput in forty-one cases, and in four cases there were waves slower than 6 per second.

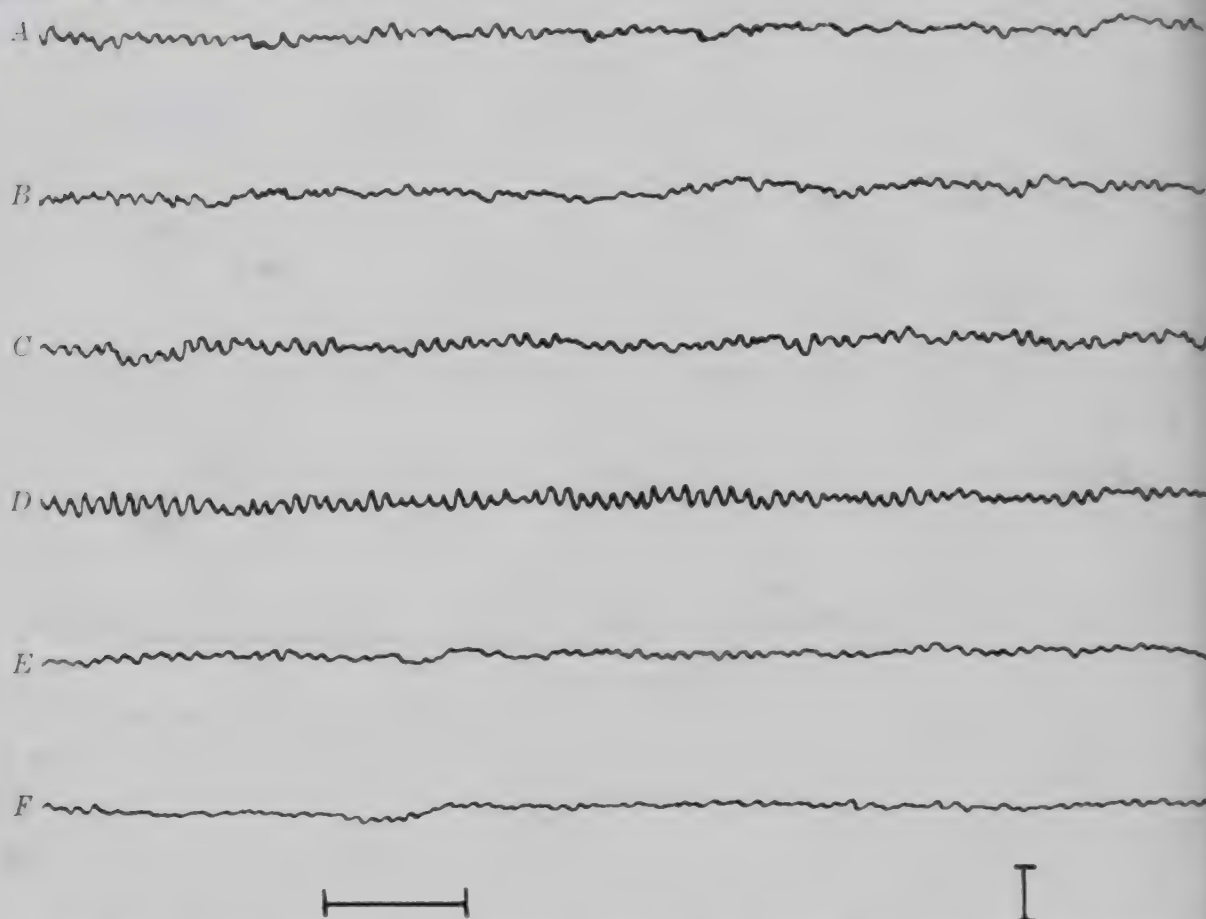


Fig. 81. Normal patterns from various areas of the cortex. Vertical bar represents 100 microvolts. Horizontal bar represents 1 second of recording time. *A*, Monopolar, left ear to left frontal area. *B*, Monopolar, left ear to left motor area. *C*, Monopolar, left ear to left parietal area. *D*, Monopolar, left ear to left occipital area. *E*, Monopolar, left ear to left temporal area. *F*, Bipolar, left frontal area to right frontal area. (Figures taken from records by Scott.)

### IRREGULARITY (INSTABILITY OF PATTERN)

In addition to the alpha rhythm, all records have a greater or less degree of irregular activity composed of a random combination of all frequencies with no repeatable pattern (Fig. 80, *C*). This may be extremely small and hardly noticeable, or it may have an amplitude as great as or greater than the alpha activity itself. It may be continuous or may fluctuate greatly in amplitude, appearing to displace the alpha rhythm at times. The degree of irregularity called "normal" varies markedly among different observers, but the following is an attempt to give some fairly generally accepted rules:

1. All records, both normal and abnormal, show some irregularity, so that this cannot be considered a criterion of abnormality per se (Fig. 80).

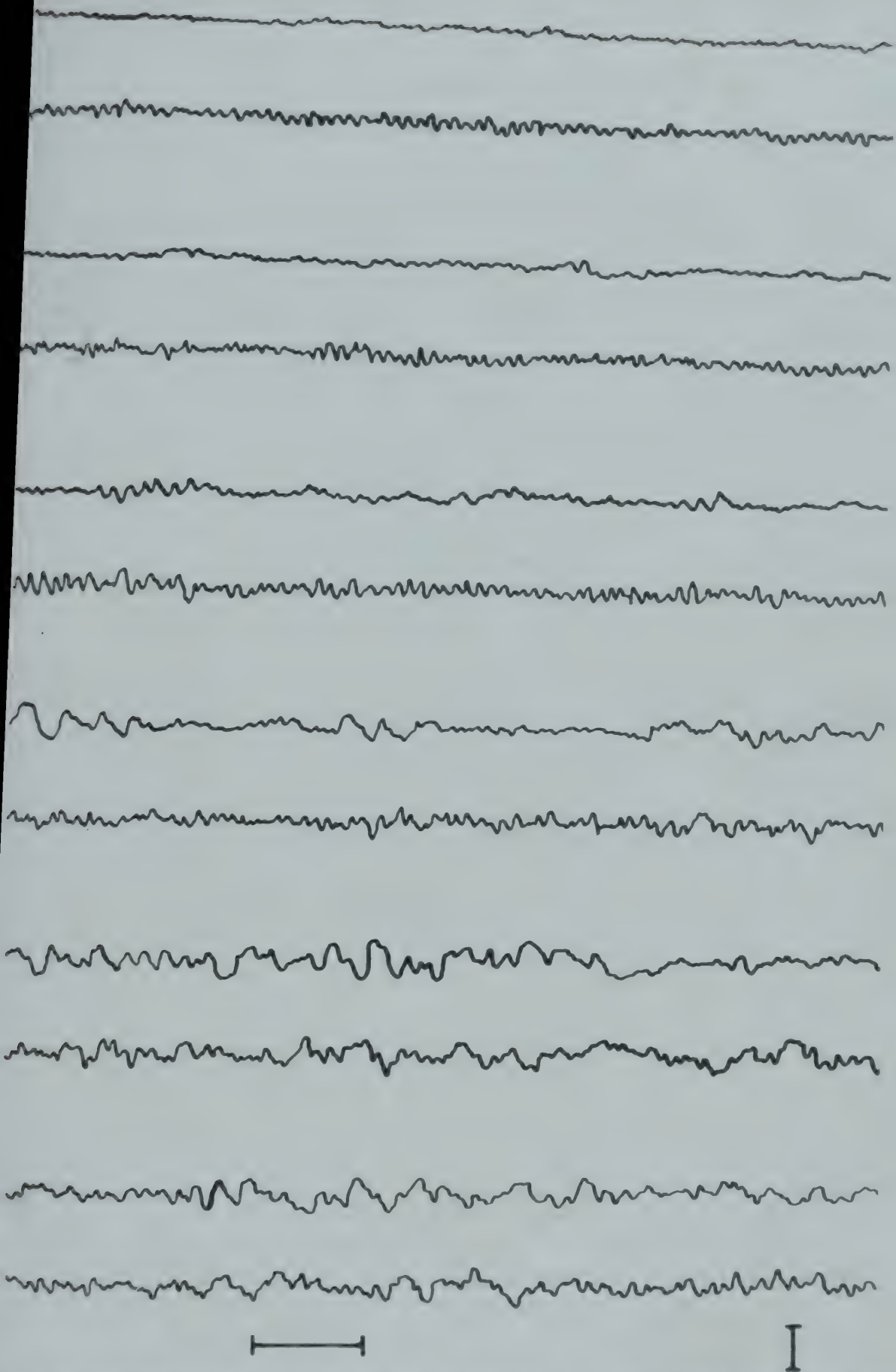


Fig. 82. Hyperventilation exercise from normal person. Exercise lasted 3 minutes, during which the subject inhaled and exhaled 15 times per minute with considerable vigor while lying in a bed with his eyes closed. In each pair of records the top line was taken bipolar between left and right frontal leads, while the lower line was taken monopolar between the right ear and the right occiput. The vertical bar represents 100 microvolts deflection. The horizontal bar represents 1 second of recording time. *A*, Resting record before exercise. *B*, After 1 minute of exercise. *C*, After 1½ minutes of exercise. *D*, After 2 minutes of exercise. *E*, After 2½ minutes of exercise. *F*, After 3 minutes of exercise. The pattern returned to that seen in *A* within 15 seconds after the end of the exercise. (Figures taken from records by Scott.)

- 2. In normal records the amplitude and persistence of the irregular activity will be approximately equal from homologous areas.
- 3. In normal records the amplitude of the irregular activity will not exceed a value of 50 to 60 microvolts when measured from monopolar leads. This is a highly debatable point, and Davis<sup>2</sup> has placed the upper limit as high as 80 microvolts. In practice, a high level of irregularity is not often found without some other form of abnormal activity, so that when it appears alone it is of questionable significance unless it is very high indeed.
- 4. The foregoing assumes that there are no recognizable slow wave components in the irregular activity. Waves with an equivalent frequency lower than 8 per second and a part of the irregular pattern should be considered like those given in the section on Slow Waves.
- 5. Where the amplitude of the alpha rhythm is low, the irregular activity may be a sign of abnormality if it is two to three times the amplitude of the alpha rhythm, even though it is not so large as 60 microvolts.

AVERAGE AMPLITUDE OF POTENTIALS

The mean peak-to-peak amplitude of the potential on any record can be measured in microvolts. McFarland and Franzen<sup>12</sup> report that the average amplitude from left to right leads in 1704 normal subjects was 56.9 microvolts, with a standard deviation of 20.3 microvolts. Williams and Reynell,<sup>16</sup> in a study of 350 normal subjects, never found differences in mean amplitude between the two hemispheres in excess of 10 per cent. Differences of more than this are occasionally found in normal persons, owing to asymmetrical thickening of the skull. Brazier and Finesinger<sup>1a</sup> found maximal potential values for monopolar occipital leads to be distributed as follows:

Total Number of Subjects	Under 25 mV	Over 25 mV, but under 50 mV	Over 50 mV, but under 75 mV	Over 75 mV, but under 100 mV	Over 100 mV
500	16	109	151	128	96

FOCAL SIGNS

As mentioned before, the normal pattern exhibits symmetry about the midline. Not only must the persistence in amplitude of the alpha activity be equal from homologous areas of the two hemispheres, but the amount of irregular activity should also be roughly equal on the two sides. In fact, any feature of the record, including suppression of normal activity<sup>16</sup> which can be localized to a given point or to one side and not the other, must find an explanation in some disturbance of normal cortical activity. Caution should be used to make sure that the electrodes are symmetrically placed, and comparison is made when the patient is fully awake.

## HYPERVENTILATION

Most electroencephalographic examinations include a two to three minute period of hyperventilation.<sup>10-11</sup> Results are shown in Figure 82.

## SLEEP

Loomis, Harvey and Hobart<sup>11</sup> and Knott, Gibbs and Henry<sup>10</sup> have described effects of drowsiness or sleep in normal persons on their electroen-

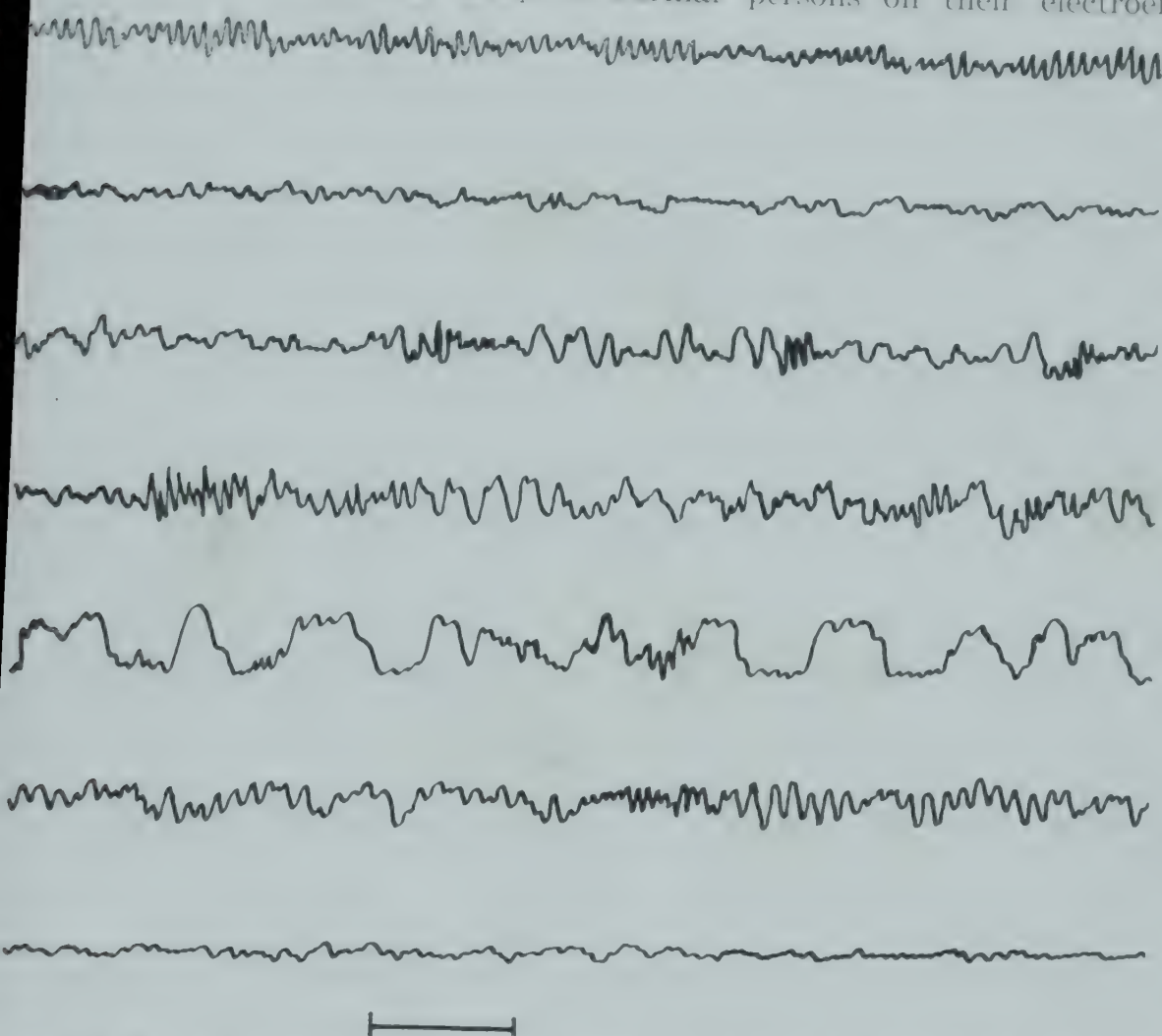


Fig. 83. Typical patterns from a normal person during sleep. All records are monopolar, ear to left occiput. The horizontal bar represents 100 microvolts deflection. The horizontal line represents 1 second of recording time. *A*, Taken while the patient was awake. *B*, The subject was drifting, 15 minutes after record *A*. *C*, The subject was sleeping lightly, 30 minutes after record *A*. *D*, Taken during moderately deep sleep, 1 hour after record *A*. *E*, Taken during deep sleep, 1½ hours after record *A*. *F*, Taken during very deep sleep, 2¼ hours after record *A*. *G*, Taken during deep sleep 4 hours after record *A*. (Gibbs, F. A., and Gibbs, E. L.: Atlas of Electroencephalography, Lew A. Cummings Company.)

cephalographic pattern. The first sign of sleep is a reduction and eventual abolition of the alpha rhythm, after which small, 14 per second waves and finally large, slow, irregular waves occur. It should be strongly stressed that the sleep pattern may appear in normal persons as early as the first feeling of drowsiness, and that great care must be taken at frequent intervals to ensure that the subject is fully awake when taking a record.

## PATTERNS IN CHILDREN

The three principal differences between the electroencephalogram of normal adults and that of children can be briefly stated.

1. The alpha frequency is below normal limits, starting at about 4 to 5 a second during the first year, reaching 6 to 7 at three years, 8 at five years, 9.3 at eight years, 9.5 at ten years, and finally attaining normal adult value at about sixteen years.<sup>7</sup>



Fig. 84. Patterns of normal activity from children below 12 years of age. All records taken monopolar, right ear to right occiput; subjects at rest, with eyes closed. The horizontal bar represents 100 microvolts. The horizontal bar represents 1 second of recording time. A, Taken from a child of 6 days; B, from a child of 9 months; C, from a child of 2 years; D, from a child of 4 years; E, from a child of 6 years; F, from a child of 8 years; G, from a child of 12 years. (Gibbs, F. A., and Gibbs, E. L.: *Atlas of Electroencephalography*, Lew A. Cummings Company.)

2. Analysis of 217 records of subjects between the ages of six and nineteen years by Henry<sup>7</sup> showed a progressive decrease in the persistence of slow waves, with a frequency of approximately 5 a second.

3. The degree of irregularity in records from normal children is greater than that in normal adults, as can be seen from sample records at different ages in Figure 84, so that the difficulty of establishing a sharply defined normal pattern increases inversely with the age of the child.

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## Chapter 37

### THE CEREBROSPINAL FLUID

THE CEREBROSPINAL fluid is produced by the choroid plexus and first appears in the lateral ventricles. From there it passes through the foramen of Monro to the third ventricle and by the aqueduct of Sylvius to the fourth ventricle. It then passes through the foramen of Magendie and the foramina of Luschka to the subarachnoid space. It is absorbed chiefly through the subarachnoid villi. There is a complete renewal of the fluid several times a day.

#### AMOUNT

The amount of fluid present in the ventriculosubarachnoid space varies considerably. Estimates are based on the amount of fluid that can be removed at lumbar puncture, by drainage or by replacing the fluid with air during encephalography. Mott<sup>33</sup> gave the volume as 100 to 150 ml. Most authorities are in agreement with his values for adults. In the newborn the amount varies from a few drops to about 5 ml. It then increases with age until it reaches the adult value.

#### PRESSURE

*The initial pressure, with a water manometer, of 100 to 200 mm. (7.5 to 15 mm. of mercury) is commonly given for clinical purposes.* Readings over 200 are considered elevated, and those between 190 and 200 are borderline. The pressure in children over six to eight years of age does not differ from that of adults.<sup>40</sup> Factors such as crying, coughing, sneezing and struggling materially affect the pressure, being sufficient to increase it by 100 mm. or more. The opinion is therefore held that such factors preclude reliable estimates in infants and young children.<sup>41</sup>

The pressure is not significantly influenced by the systolic or diastolic blood pressure. Changes in venous pressure are accompanied by similar changes in the cerebrospinal fluid pressure.

Ayer<sup>1</sup> indicated that in the sitting position the lumbar pressure is approximately doubled, while at the cisterna magna the pressure is less than zero, i. e., negative; similarly, the ventricular pressure is negative.

#### QUECKENSTEDT TEST

Normally, the cerebrospinal fluid pressure rises when both jugular veins are compressed, and the rise quickly disappears when the pressure is released. This is called the *Queckenstedt sign*. Compression on one jugular vein does not increase the pressure. Increase of pressure when one jugular vein is compressed indicates an obstruction or thrombosis of the lateral sinus on the opposite side.

## PHYSICAL PROPERTIES

The spinal fluid is colorless and clear. No sediment settles out upon standing, does it coagulate.

The normal range of specific gravity for lumbar fluid may be taken as 1.005 009; of the ventricular fluid, 1.002 to 1.004.<sup>42</sup>

The viscosity of spinal fluid compared with water as unity is from 1.020 to 1.027 at 38° C.<sup>29</sup> These measurements were made with an Ostwald viscosimeter. Using Traube's stalagmometer, Polyáni<sup>37</sup> reported the surface tension of four different samples of spinal fluid to be 7.35, 7.15, 7.16, and 7.20 dynes per cm at 20° C.

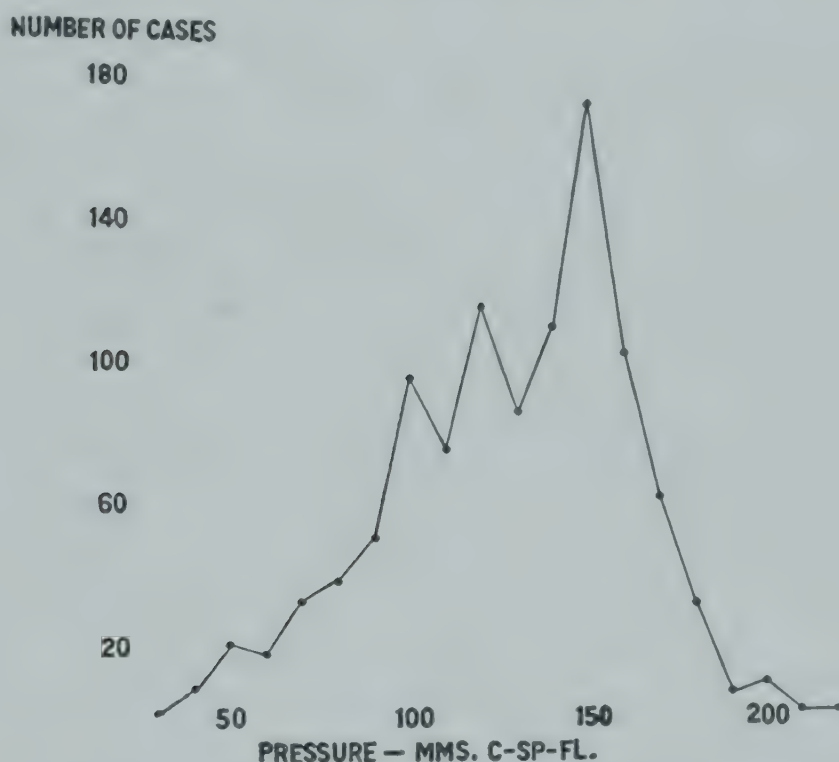


Fig. 85. Curve showing the distribution of the cerebrospinal fluid pressures in 1033 patients who had a normal blood pressure and in whom there was no evidence of an inflammatory or standing lesion within the central nervous system. (Merritt, H. H., and Fremont-Smith, F.: Cerebrospinal Fluid.)

## ELECTRICAL CONDUCTIVITY

Eckel<sup>11</sup> studied twenty-six cases and found the range to be 0.01425 to 0.01549 mhos at 25° C., with an average of 0.01425. Polyáni's<sup>37</sup> values range from 0.01136 to 0.01527 mhos at 20° C.

## FREEZING POINT

The freezing point is 0.56° to 0.60° C.<sup>9</sup>

## REFRACTIVE INDEX

Polyáni<sup>37</sup> found the refractive index in four different samples of cerebrospinal fluid to be 1.3499 at 23° C., 1.33516 at 21° C., 1.33579 at 20.3° C. and 1.33554 at 20° C.

CHEMICAL COMPONENTS

HYDROGEN ION CONCENTRATION (pH). *The normal range is from 7.35 to 7.40 ± 0.02.*<sup>31a, 32</sup> McQuarrie and Shohl<sup>31a</sup> showed that the pH values of spinal fluid and of blood plasma are about the same, provided measurements are made at 38° C. and the sample is protected against loss of carbon dioxide.

ALBUMIN. See Protein on page 317. Albumin constitutes about 80 per cent of the spinal fluid proteins.

AMINO ACID NITROGEN. The normal range is:

1.2 to 2 mg./100 ml.<sup>43</sup>  
1.5 to 3 mg./100 ml.<sup>31</sup>

BICARBONATE. *The normal range is 40 to 60 volumes per cent.*<sup>16, 38</sup>

CALCIUM. Cohn, Kaplan and Levinson<sup>5</sup> studied twenty normal fluid specimens obtained by lumbar puncture and found the calcium concentration to vary from 4.1 to 5.9 mg. per 100 ml. (average, 5.0 mg. or 2.5 mEq. L.) (see Table 182).

CHLORIDES. Fremont-Smith and Dailey<sup>17</sup> found the normal chloride concentration to be the same in lumbar, cisternal and ventricular fluids. This is in agreement with the results of others (see Tables 181 and 182).

TABLE 181  
CHLORIDE CONCENTRATION OF NORMAL CEREBROSPINAL FLUID\*

Age	Number of Cases	Normal Range	
		Mg./100 ml. (as NaCl)	mEq./L.
7 Days to 3 months.....	10	636-716	108.8-122.5
4 Months to 12 months.....	10	659-742	112.7-128.5
13 Months to 12 years.....	30	683-763	116.8-130.5
Adults.....	..	697-748	119.1-127.9

\* Lumbar fluid. The values for children are taken from Stewart;<sup>41</sup> those for adults from Merritt and Fremont-Smith.<sup>32</sup> The latter agree closely with those of other investigators.

CHOLINE. Gumprecht<sup>21</sup> and Kopetzky<sup>26</sup> reported minute quantities of choline.

CARBON DIOXIDE-COMBINING POWER. The carbon dioxide-combining power varies at different levels.<sup>23</sup> *The normal range is 40 to 60 volumes per cent (see Bicarbonate) (see also Table 182).*

CHOLESTEROL. Plaut and Rudy<sup>36</sup> found cholesterol in normal fluids to range from 0.06 to 0.22 mg. per 100 ml.

CREATININE. Cockrill<sup>3</sup> found the normal range of creatinine to be 0.54 to 1.91 mg. per 100 ml.

ELECTROLYTES. The normal concentrations of anions and cations in spinal fluid are given in Table 182.

GLOBULIN. See Protein on page 317. Globulin constitutes about 20 per cent of the spinal fluid proteins.

IODINE. According to Everett,<sup>44</sup> the iodine concentration is 0.58 γ per 100 ml.

LACTIC ACID. The normal range is:

9 to 15 mg./100 ml.<sup>24</sup>  
11 to 27 mg./100 ml.<sup>18</sup>

MAGNESIUM. The normal concentration is usually given as 1 to 3.5 mg. per ml.; 5 mEq./L. by Shohl (Table 182).<sup>4, 15, 40</sup>

TABLE 182  
ELECTROLYTES IN CEREBROSPINAL FLUID  
(Shohl, 1939)<sup>39</sup>

Cations	mEq./L.	Anions	mEq./L.
	151	PO <sub>4</sub> as P	1
	4	SO <sub>4</sub> as S	1
	3	Cl	125
	5	CO <sub>2</sub>	28
Total	163	Total	155

PHOSPHORUS. Cohn, Kaplan and Levinson<sup>5</sup> studied thirteen normal spinal fluid specimens obtained by lumbar puncture and found the phosphorus concentration to be between 1 and 1.5 mg. per 100 ml. (average, 1.4 mg.) (see Table 182).

POTASSIUM. The normal range is:

11 to 16 mg./100 ml.<sup>28</sup>  
11 to 15 mg./100 ml.<sup>32</sup>  
4 mEq./L. (Table 182).<sup>39</sup>

PROTEIN. The ventricular fluid contains much less protein than does the lumbar fluid. Fluid from the cisterna magna contains more protein than that from the ventricle and less than that from the lumbar region. According to Texner,<sup>16</sup> about 80 per cent of the protein is albumin. Fibrinogen is not present. The normal range is:

Adults, 15 to 45 mg./100 ml.<sup>32</sup>  
Children, 15 to 55 mg./100 ml.<sup>41</sup>

SODIUM. The normal range is 301 to 343 mg. per 100 ml. (131 to 149 mEq. per liter).<sup>8</sup> According to Shohl, the average value for sodium is 151 mEq. L. (Table 182).

SUGAR (GLUCOSE). Glucose is a normal constituent of the cerebrospinal fluid and appears to be derived from the blood.

Ayer and Solomon<sup>2</sup> found the average value for sugar greater in ventricular fluids than in the lumbar fluid, and the cisternal fluid value somewhere between the two.

Stewart<sup>3</sup> found the ventricular fluid in children to be higher than the

cisternal or lumbar fluid values. The values for adults were within the normal range, with no significant differences between cisternal and lumbar fluids.

The normal range is:

Adults, 45 to 80 mg./100 ml.<sup>16</sup>

Adults, 40 to 66 mg./100 ml.<sup>6</sup>

Children, 71 to 90 mg./100 ml. 6 months to 10 years of age.<sup>6</sup>

Nonglucose-reducing substances are included in the figures reported as sugar. *The average of nonglucose-reducing substances in spinal fluid is 4 mg. per 100 ml.*<sup>32</sup>

In Table 183 is given a comparison of the concentrations of serum and spinal fluid sugar.

TABLE 183

CONCENTRATION OF GLUCOSE IN CEREBROSPINAL FLUID COMPARED WITH THAT OF SERUM  
(Merritt and Fremont-Smith, modified)<sup>32</sup>

<i>Number of Cases</i>	<i>Serum Sugar Values (Mg./100 ml.)</i>	<i>Spinal Fluid Sugar Values (Mg./100 ml.)</i>
3.....	64- 75	47- 57
62.....	75-100	47- 78
56.....	100-125	55- 93
14.....	125-150	65-139
15.....	150-200	73-112
2.....	200-300	89-156

TOTAL BASE. *The average normal value is approximately 155 milliequivalents per liter.*<sup>22, 34</sup>

UREA NITROGEN. The urea nitrogen concentration corresponds closely to that of the blood.<sup>7</sup> The occasional difference between spinal fluid and blood may be due to the rapid rise and fall of blood urea nitrogen during protein digestion.

The normal range is:

10 to 15 mg./100 ml.<sup>6</sup>

7 to 13.5 mg./100 ml.<sup>29</sup>

## ENZYMES

Amylase, oxidase and lipase are present in small amounts.<sup>24</sup> Glycolytic enzymes are not present.

## HORMONES

Pituitary hormones are present in the cerebrospinal fluid.<sup>24</sup>

## VITAMINS

Vitamin C is present in quantities corresponding to those in the blood.<sup>2</sup>

## IMMUNOLOGICAL COMPONENTS

Bacteriolysins, antitoxins, precipitins and agglutinins are not normally present in cerebrospinal fluid.

The Wassermann and flocculation tests for syphilis are normally negative. Complement is not normally present.

COLLOIDAL TESTS

COLLOIDAL GOLD TEST.<sup>27</sup> *This is normally negative, i. e., giving no reduction on any dilution (00000000000).* Occasionally a normal fluid may give a slight reaction in one or more tubes. Reactions should be over 1 in one or more tubes to be considered significant.

Merritt and Fremont-Smith<sup>32</sup> consider any change in the color of the solution less than lilac ("2") of no significance. The interpretation of a lilac color change ("2") is somewhat difficult, since it occurs in many otherwise normal specimens and in those from patients with no evidence of any abnormality of the central nervous system.

COLLOIDAL MASTIC TEST.<sup>12</sup> *Normal fluids give negative (00000) reactions to this test.*

COLLOIDAL BENZOIN TEST.<sup>19</sup> *A normal reaction is usually indicated by no precipitation; however, according to Guillain and L  chelle,<sup>20</sup> there may normally be some precipitation in one or two tubes of numbers 5 to 8, inclusive. Evans and Dodson<sup>13</sup> consider as normal precipitation less than grade 2 occurring in more than three tubes in a zone.*

TAKATA-ARA REACTION. *Cerebrospinal fluid normally gives a negative reaction to this test. The reaction is negative when the mixture remains clear or when there is only a slight opacity after thirty minutes.*

POTASSIUM PERMANGANATE TEST

The result of this test is expressed as an index, indicating the amount of organic matter measured by the reduction of a standard solution of potassium permanganate.

The normal range is:

Lumbar index, 1.3 to 1.8<sup>29</sup>  
Cisternal and ventricular index, 1.1 to 1.5<sup>25</sup>

CYTOLOGY

TOTAL CELL COUNT. *Normally there are from 0 to 5 cells per cubic millimeter of cerebrospinal fluid. A high percentage have no cells. The fluid from the cisterna magna and lateral ventricles contains less cells than that from the lumbar*

TABLE 184

ROUTINE CELL COUNTS OF 1219 SPINAL FLUID SPECIMENS\*

Unpublished data from laboratories of the Graduate Hospital, University of Pennsylvania, Philadelphia)

<i>Number of Cells per Cubic Millimeter</i>	<i>Number of Specimens</i>	<i>Per Cent</i>
None.....	660	54.1
1-5.....	524	43.0
6-8.....	14	1.1
9-10.....	4	0.3
Over 10.....	17	1.4

\* All specimens were from patients without spinal fluid changes indicative of central nervous system involvement.

region. Fluids having 5 to 8 cells are usually considered borderline. For clinical purposes some consider 10 cells as a high normal value.

According to Levinson and MacFate,<sup>8\*</sup> in normal children under one year of age the fluid may contain as many as 30 cells per cubic millimeters; from one to four years of age, 20 cells; and from five years of age to puberty, about 10 cells.

**DIFFERENTIAL COUNT.** Normally, only lymphocytes are present; on rare occasions, however, neutrophils or endothelial cells may be found.

TABLE 185

## RÉSUMÉ OF NORMAL VALUES FOR CEREBROSPINAL FLUID\*

Amount	100-150 ml.
Cell count	See Table 184
Pressure	100-200 mm. of water 7.5-15 mm. of mercury
Specific gravity	1.005-1.009
Viscosity	1.020-1.027 at 38°C.
Surface tension	7.35, 7.15, 7.16, 7.20 dynes/cm. at 20°C.
Conductivity	0.01425-0.01549 at 25°C.
Freezing point	-0.56°-0.60°C.
Refractive index	1.33554 at 20°C.
Hydrogen ion concentration (pH)	7.35-7.40 at 38°C.
Albumin	Approximately 80% of protein
Amino acid nitrogen	1.5-3 mg./100 ml.
Bicarbonate	40-60 vol. per cent
Calcium	4.1-5.9 mg./100 ml.
Carbon dioxide-combining power	40-60 vol. per cent
Chlorides	697-748 mg./100 ml.
Cholesterol	0.06-0.22 mg./100 ml.
Creatinine	0.54-1.91 mg./100 ml.
Electrolytes	See Table 182
Globulin	Approximately 20% of protein
Glucose	See <i>Sugar</i>
Iodine	0.58γ/100 ml.
Lactic acid	9-27 mg./100 ml.
Magnesium	1-3.5 mg./100 ml.
Phosphorus	1-1.5 mg./100 ml.
Potassium	11-16 mg./100 ml.
Protein	15-45 mg./100 ml.
Sodium	301-343 mg./100 ml.
Sugar	40-80 mg./100 ml.
Total base	155 mEq./liter
Urea nitrogen	7-15 mg./100 ml.

\* For source of values and for additional information, see text.

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Section VII

THE URINARY SYSTEM

(Normal Values in Urology)



## Chapter 38

### THE KIDNEYS

#### URINARY SYSTEM

The URINARY system is made up of the kidneys, the most vital of the excretory organs, together with a sequence of musculomembranous tubes, the ureters and urethra, separated by the bladder, a hollow organ located in the urinary tract between the ureters and the urethra. The function of the ureters and urethra is to transport the urine, whereas the bladder acts as a reservoir which stores the formed urine and expels it at proper intervals of time. In the female system is intimately associated with, but completely separate from, the genital organs; in the male these two systems are combined.

The male genital tract consists of a series of specialized glandular organs—the testes, prostate, seminal vesicles and so on, and the ducts which carry their secretions to the posterior part of the urethra. The male urethra serves both as a urinary and genital organ in that it transports urine and the seminal fluid, as well as contains certain glands which contribute to the formation of the seminal fluid.

#### KIDNEYS

The kidneys are the organs which form urine and which have the physiologic functions associated with urine formation and secretion. There are two kidneys, located deep in the loins behind the peritoneum, one on each side of the vertebral column and the great vessels. The characteristic form of the kidney is that of a lima bean, with an upper quite rounded pole and a lower less rounded pole, an outer convex and an inner concave margin. The inner border has a notch, the hilum, which is the opening or entrance to the renal sinus. The anterior surface is somewhat convex; the posterior is almost flat. Variations in the form and degree of rotation of the kidney are not uncommon. The surface is smooth and covered by a thin, fibrous renal capsule. The organ is dark brownish-red in color.<sup>4, 5</sup>

**SIZE AND POSITION.** The adult kidney is roughly 9 to 12 cm. long, 4 to 6 cm. wide, and 3 to 4 cm. in thickness at the hilum (see Table 186).

The left kidney is usually longer and narrower than the right. The upper pole is longer and more rounded than the lower pole and is situated closer to the midline.<sup>4</sup> The adrenal glands are in direct relation to the upper pole of the kidney, of which it covers the medial and anterior parts. The inferior pole is smaller and thinner and diverted away from the midline. The relations of the kidney to adjacent viscera vary completely from one side to the other.

The upper end of the kidney is at the level of the twelfth dorsal vertebra, and the lower end at the level of the middle of the body of the third lumbar

vertebra. The right kidney lies 1 to 2 cm. lower than the left kidney.\* The distance from the highest point on the iliac crest to the lower pole of the normally situated kidney is reported by Goldstein<sup>1</sup> to be 5 to 5.5 cm. and by Cunningham<sup>1</sup> to be 3 to 5 cm. This interval is greater on the left.

**WEIGHT.** The ratio of the weight of the two normal kidneys in the adult to the body weight is about 1 to 240. The kidney in the male is somewhat larger than in the female. The weights noted by leading texts and authors are: Eisen-

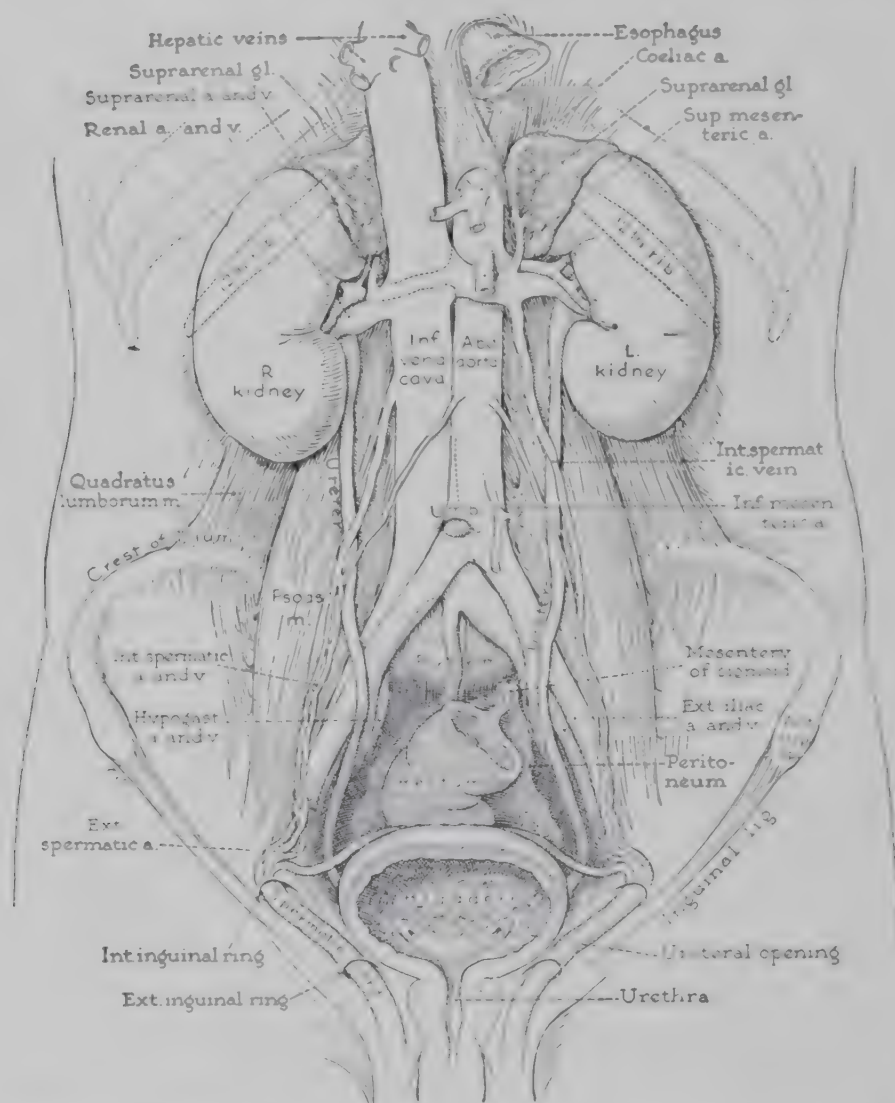


Fig. 86. Topographic relations of urinary system and spermatic cord. (Jones and Shepard: *Manual of Surgical Anatomy*.)

drath and Rolnick,<sup>3</sup> 168 gm. average weight; Gray,<sup>5</sup> 125 to 170 gm. in the average adult woman; Wesson,<sup>10</sup> 168 gm. average weight; and Goldstein,<sup>1</sup> 110 to 140 gm. when weighed without vessels and blood and 135 to 165 gm. with vessels and blood.

The weight of the kidney varies with age. Wald,<sup>8</sup> in a careful statistical study of the weight of normal human kidneys, found that the median weight of both kidneys in men in the third decade of life was about 308 gm. He found that the weight increases slightly through the third and fourth decades, when

reaches about 320 gm., and then decreases to about 260 gm. in the eighth decade. In women the mean weight of both kidneys was approximately 60 gm. less than for men and follows the same general trend with age.

The kidneys in the newborn are about three times as large in proportion to the body weight as in the adult.<sup>5</sup> The actual weight is about one-twelfth that of the adult. The kidney doubles its weight in six months, triples it in twelve months, and at five years is five times that at birth.<sup>7</sup>

TABLE 186  
SIZE OF NORMAL KIDNEY

Length in Centimeters	Width in Centimeters	Thickness in Centimeters	Investigator
2-3	4.5-6.5	2.5-3.5	Goldstein (1945)
	6	3.9	Eisendrath and Rolnick (1938)
2.5	5-7.5	2.5+	Gray (1942)
	6	3	Davis (1934)
	5	3	Cunningham (1943)
1.2	3-4	5-6	Wesson (1946)

TABLE 187  
NORMAL WEIGHT (IN GRAMS) OF BOTH KIDNEYS ACCORDING TO AGE AND SEX  
(Wald, 1937)<sup>8</sup>

Men					Women			
Age (Years)	Number of Weights	Mean Weight $\pm$ S. E.*	Standard Deviation	Coefficient of Variation (Per Cent)	Number of Weights	Mean Weight $\pm$ S. E.	Standard Deviation	Coefficient of Variation (Per Cent)
0-29	55	313 $\pm$ 7.96	59.0	18.9	29	257 $\pm$ 10.11	54.5	20.2
30-39	72	323 $\pm$ 6.72	57.0	17.6	21	250 $\pm$ 10.39	47.6	19.1
40-49	81	316 $\pm$ 6.04	54.4	17.2	21	258 $\pm$ 11.52	52.8	20.5
50-59	46	294 $\pm$ 7.66	52.0	17.6	13	254 $\pm$ 18.46	66.5	26.2
60-69	36	293 $\pm$ 10.89	65.3	22.2	17	218 $\pm$ 9.79	40.4	18.5
70-79	17	253 $\pm$ 7.78	32.1	12.7	5	236 $\pm$ 22.24	49.7	21.1

\* Standard error of the mean.

**FIXATION AND MOTILITY.** The normal kidney is not rigidly fixed in its anatomical position. The kidney and its vessels are imbedded in a mass of fat, which becomes well developed by the tenth year and, together with the renal fascia, provides the organ with its immediate support. Further stabilization is provided mainly by the pressure and counterpressure exerted upon it by neighboring structures.<sup>1, 4, 5</sup>

The kidneys move with respiration and with alterations in the position of the body. The right kidney is more mobile than the left kidney, that in the female more so than in the male. The normal excursion of the kidney in the female is 1.5 to 5 cm., and in the male about one-half as great.<sup>10</sup>

## RENAL PELVIS AND CALICES

The renal pelvis is located at the hilum of the kidney, partly inside and partly outside the kidney proper. It is pyramidal, having a triangular or funnel shape. It is made up of six to fourteen minor calices which may be divided into an upper, middle and lower group and which lead into two to four major calices, which blend into the sinus of the pelvis.<sup>4, 10</sup> Wesson<sup>10</sup> describes a normal renal pelvis as "one in which the drainage system of the kidney is symmetrically placed throughout the renal tissue, furnishing a free flow of urine through all its parts, from minor to major calices, to pelvis, to ureter, to bladder."

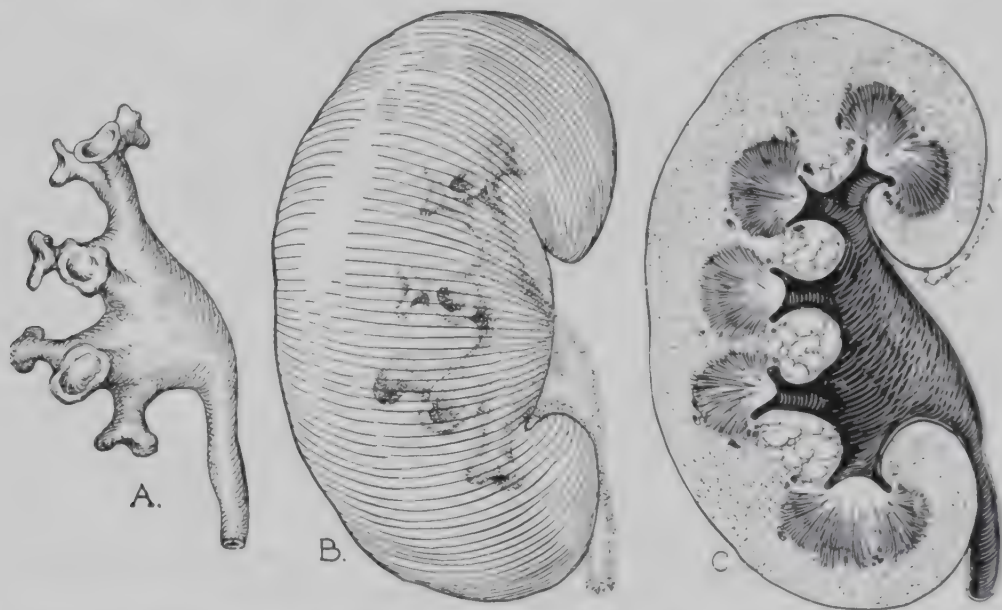


Fig. 87. Schematic diagrams of normal kidney pelvis, showing the major calices and the minor calices. (Wesson, M. B.: *Urologic Roentgenology*, Lea & Febiger.)

The renal pelvis is wide at its base, and at its apex merges gradually into the ureter. Goldstein<sup>4</sup> states that the pelvis measures from 1.8 by 1.8 to 2.1 by 2.1 cm., and that its capacity is 5 to 11 ml. Wesson<sup>10</sup> found the average pelvic capacity to be 7.5 ml., with volumes up to 20 ml. considered normal in some cases. The intrapelvic pressure has been found to be 35 to 45 mm. of mercury.<sup>9</sup>

**POSITION OF THE PELVIS.** The superior calyx is normally seen on urographic films at about the level of the twelfth rib or a short distance below it. It may be seen as high as the tenth intercostal space or as low as the third lumbar vertebra. The uteropelvic junction usually lies at the end of the transverse process of the second lumbar vertebra. The median border of the pelvis is seen close to the vertebra or overlying the transverse processes. The right renal pelvis may be 3 to 4 cm. below the left.<sup>10</sup>

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## Chapter 39

### TESTS OF RENAL FUNCTION

A VARIETY OF tests have been devised to measure the function of the kidneys in health and in disease, but relatively few of these are of clinical usefulness. These include clearance tests, concentration tests and measurement of the concentration of certain blood constituents. Other tests are also mentioned in this section, though admittedly they yield limited information.<sup>17</sup>

It should be emphasized that all renal function tests may be influenced by nonrenal factors, particularly those which may impair renal nutrition. For example, apparent renal functional impairment may be seen in severe anemia and in cardiac failure. In such states, when the hemoglobin level is raised or when cardiac compensation is restored, renal function may improve.

#### CLEARANCE TESTS

In essence, clearance tests measure the volume of blood cleared of a given solute in a measured interval of time<sup>32</sup> and in so doing yield quantitative measurement of renal function. Anything decreasing the renal blood flow or increasing the glomerular blood pressure will alter the result of the clearance test even though no true renal damage is present. The technics of the various tests differ somewhat, but the calculation of the rate of clearance is similar for all substances. The rate of clearance is equal to  $\frac{UV}{B}$  where  $U$  is the concentration of a given solute in urine,  $B$  is the concentration of the solute in the serum or plasma, and  $V$  is the urinary volume, expressed as milliliters per minute. Corrections must be applied for variations in surface area.

**UREA CLEARANCE.**<sup>28</sup> Although about 40 per cent of urea excreted by the glomeruli is reabsorbed in the tubules, the urea clearance ordinarily bears a direct relation to the amount of glomerular filtration and thus is a useful measure of glomerular function.

The subject empties his bladder at the beginning of the test and discards this specimen. At the end of one and two hours, both periods being accurately timed, urine specimens are collected and their volumes accurately measured. A blood sample is drawn a few minutes before the end of the first hour. The concentration of urea in the blood and urine is determined, and the amount of blood cleared of urea is calculated from the formula  $\frac{UV}{B}$ ,  $B$  being the concentration of urea in the blood. As Austin, Stillman and Van Slyke<sup>33</sup> showed, this formula is applicable, however, only if the rate of urine formation is greater than 2 ml. per minute (maximal clearance). If the rate is less than 2 ml. per minute, the urea clearance is calculated from the formula  $\frac{U \times V}{B}$ , where  $U$ ,  $B$  and  $V$  have the same meaning as before (standard clearance). *In the normal*

fect the rate of maximum clearance is about 75 ml. per minute. The test is usually reported as percentage of average normal function, the range being between 75 and 125 per cent.

In the normal newborn the urea clearance value is about one-half that of normal adult. The value rises gradually to approach adult values at the beginning of the second year of life. The low values in the newborn are due, in large measure, to relatively less glomerular filtration.<sup>36</sup>

The urea clearance may vary widely during pregnancy (Table 188).

**INULIN CLEARANCE.**<sup>7</sup> This substance is apparently excreted only by the glomeruli. Since neither reabsorption nor excretion seems to occur through the tubules, the rate of inulin clearance may be regarded as a measure of the rate

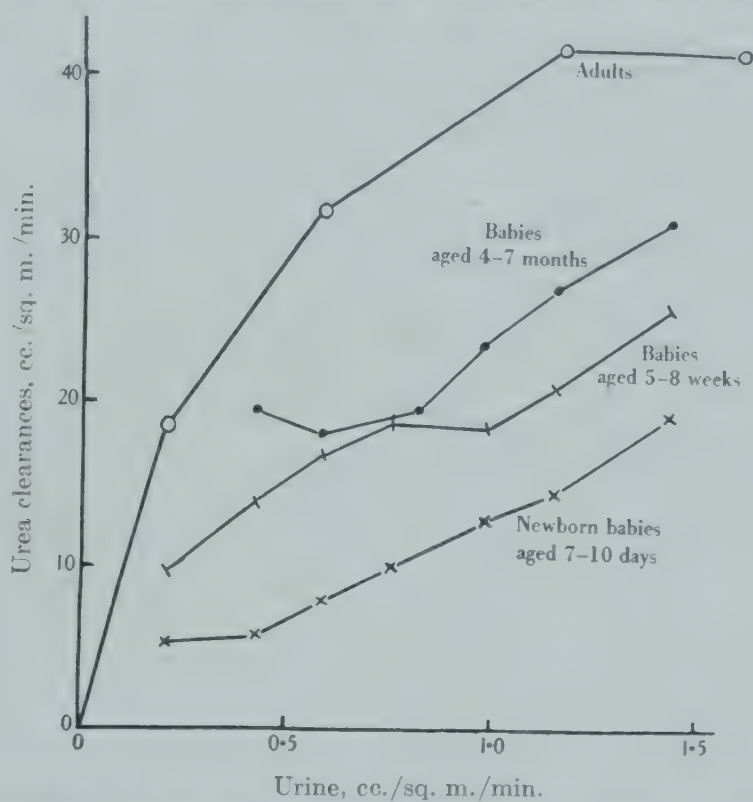


Fig. 88. Comparison of the average urea clearances of adults and of infants at three different ages, on the basis of body surface. (After McCance, R. A., and Young, W. F.: *J. Physiol.*, vol. 99.)

glomerular filtration. Ten grams of inulin dissolved in 100 ml. of saline are given intravenously over a period of ten minutes, or the intravenous drip technique of Smith<sup>38</sup> may be used. Apparently similar results are obtained by using either of the two methods of conducting the test. *Normal values are 120-130 ml. of plasma cleared of inulin per minute.* In the normal newborn the values are about one-half that of the normal adult.

**CREATININE CLEARANCE.** Steinitz and Turkand<sup>40</sup> reported that creatinine is excreted in part by way of the tubules, if it is present in the serum in large quantities. However, at levels normally encountered it seems to be excreted wholly by the glomeruli. Creatinine is evidently not reabsorbed by the tubules.

**EXOGENOUS CREATININE CLEARANCE.**<sup>33, 40</sup> The subject ingests 4 gm. of creatinine in 150 ml. of water. One hour later the bladder is emptied and the urine

discarded. A blood sample is drawn immediately thereafter. Exactly one hour later the bladder is emptied and the specimen is saved. A second blood sample is drawn immediately thereafter. The creatinine clearance is calculated from the concentration of creatinine in the urine, the volume of the specimen and the mean concentration of creatinine in the two blood samples. *In the normal subject the rate of clearance averages 152 ml. per minute.*

ENDOGENOUS CREATININE CLEARANCE.<sup>40</sup> This test is conducted in the same manner as the urea clearance test. The concentration of creatinine in the blood and urine is determined and the urinary volume is measured. *In the normal subject the rate of clearance seems to be the same as that of inulin, namely, about 125 ml. per minute.*

TABLE 188  
UREA CLEARANCE IN NORMAL PREGNANT PATIENTS  
(After Bodansky and Bodansky, 1940)<sup>12</sup>

Number of Cases	Ante Partum Clearance—Per Cent		Post Partum Clearance—Per Cent		Investigator
	Average	Range	Average	Range	
4 .....	100	92–102	..	..	Stander
5 .....	127	83–161	..	..	Hurwitz and Ohler
38 .....	72	29–184	..	..	Cantarow and Ricchiuti
9 .....	123	..	104	..	Cadden and McLane
27 .....	102	40–179	125	50–179	Dieckmann
13 .....	153	80–286	96	61–120	Nice
19 .....	85	60–118	..	..	Elden and Cooney
43 .....	107	60–148	112	70–175	Chesley

RENAL BLOOD FLOW.<sup>36, 38</sup> By effective renal blood flow is meant the actual volume of blood that comes into contact with functioning nephrons (glomeruli and tubules). It does not include flow through capsular anastomoses or inactive nephrons. If a substance is not synthesized in the kidney and the plasma is cleared of all it contains, the limit of its clearance equals that contained in blood.

DIODRAST CLEARANCE. Diodrast, which is entirely in the plasma, is excreted principally by way of the renal tubules, and its removal from the plasma as it flows through the kidney is nearly complete. Hence its clearance value is a measure of the total renal plasma flow, from which the renal blood flow may be calculated. The test is conducted in the same manner as the inulin clearance test, using the intravenous drip technic. One per cent solutions of diodrast in saline are usually used. *Normal diodrast clearance or total renal plasma flow in the normal subject is 520 to 1560 ml. per minute.*<sup>15, 19</sup> Hippuran may be substituted for diodrast, and similar values are obtained.

TUBULAR EXCRETORY MASS CALCULATION.<sup>38</sup> The term “tubular excretory mass” is used to designate the total mass of intact tubular excretory tissue in the kidney. If a substance, in addition to being filtered through the glomeruli,

also excreted by the tubular epithelium (as in diodrast), its clearance will exceed the rate of glomerular filtration (inulin clearance) by an amount equal to the extent of the tubular clearance. The maximal rate of tubular excretion is calculated by the difference between total urinary excretion per minute and the quantity excreted by filtration. From the results of simultaneous inulin and diodrast clearance tests, an index of the mass of functioning tubular tissue may be calculated from the formula

$$T_m = UV - PCWF$$

where  $T_m$ , the maximal tubular excretion of diodrast, is an index of functioning tubular mass,  $U$  is the concentration of diodrast in the urine,  $V$  is the urinary volume,  $P$  is the concentration of plasma diodrast,  $C$  is the inulin clearance in milliliters per minute,  $W$  is the fraction of water in the plasma, and  $F$  is the fraction of diodrast free in the plasma. *The normal maximum tubular excretion of diodrast ranges from 36 to 72 mg. of iodine per 1.73 square meters of body surface per minute. The average excretion for men is 53.3 and for women, 46.7. Maximum tubular excretion of diodrast can also be calculated from the urea clearance.*<sup>16</sup>

**TESTS RELATED TO THE CLEARANCE TESTS.** Before the clearance tests were devised in their present form, several other tests based upon similar principles were in use. These are mostly of historical interest, but will be briefly presented for the sake of completeness.

**AMBARD'S CONSTANT.** Ambard<sup>9</sup> showed that the rate of excretion of urea varies directly as the square of the concentration of urea in the urine. Mathematically this relationship is expressed as

$$\frac{U_r}{\sqrt{\frac{D\sqrt{C}}{5}}} = K$$

where  $U_r$  is the concentration of urea in blood,  $C$  is the concentration of urea in urine (both expressed in grams per liter), and  $D$  is the rate of urea excretion in grams per twenty-four hours. In the normal subject  $K$  is about 00.7 for a man of 70 kg. Higher values indicate renal impairment.

**MCLEAN'S INDEX.** The calculation of Ambard's constant was modified by McLean<sup>27</sup> as follows:

$$\text{Index} = \frac{\text{Grams of urea /24-hours} \times \sqrt{\text{grams of urea /liter of urine}} \times 8.96}{\text{Weight in kg. (grams urea /liter of blood)}^2}$$

*In the normal subject the value of the index is 100.*

**ADDIS RATIO.** According to Addis,<sup>3</sup> the ratio

$$\frac{\text{Mg. of urea in 1 hour's urine}}{\text{Mg. of urea in 100 ml. of blood}}$$

is a measure of the functioning kidney parenchyma, provided the blood contains sufficient urea to tax the excretory function of the kidney. The ratio is determined after giving 1 liter of water by mouth with 20 gm. of urea added if the blood urea is not already elevated. *In the normal subject the value of the ratio is 35 to 60.*

## CONCENTRATION AND DILUTION TESTS

Concentration tests are the most sensitive of all renal function tests, as well as the easiest to perform. They may indicate the presence of renal damage in instances where the clearance tests give normal values. Concentration tests may, however, give misleading information in the presence of frank or occult edema. Moreover, the tests depend upon the patient's obedience and cooperation. They may give a roughly quantitative measurement of the degree of damage in the early stages of renal disease, but when the maximal attainable specific gravity is 1.010, further progression of renal damage is not reflected in the specific gravity values. The dilution tests give essentially similar information to that obtainable from the concentration tests, but usually do not become abnormal until after the latter indicate parenchymal damage.<sup>37</sup> Both types of test may yield information regarding renal damage even when the concentration of the nonprotein nitrogenous components of the blood is within the normal range. The normal infant shows poor concentrating ability during the first year of life.<sup>36</sup>

In measuring specific gravities, corrections should be made if albuminuria or glycosuria is present. Subtract 0.001 from the observed specific gravity for each 3.9 gm. of albumin or for each 2.7 gm. of glucose per liter.<sup>6</sup> Correction for protein may also be made by the formula of Lashmet and Newburgh:<sup>22</sup>

$$\text{Specific gravity correction} = 0.003 \times \text{per cent protein.}$$

If correction of specific gravity is desired in other urinary constituents, 0.001 is subtracted from the specific gravity for each 3.8 gm. of sodium acid phosphate, 1.47 gm. of sodium chloride, or 3.6 gm. of urea per liter. The presence of diodrast in the urine may give an extremely high specific gravity.

## TESTS DEPENDING UPON URINARY SPECIFIC GRAVITY

Numerous methods of performing the concentration test have been proposed. Many are of historical interest only. Tests frequently used are those of Addis and Shevky<sup>4</sup> and Sodeman and Engelhardt.<sup>39</sup> The former is suited to hospitalized patients; the latter is useful in office practice, especially for children.

**CONCENTRATION TEST OF ADDIS AND SHEVKY.**<sup>4</sup> The subject abstains from all fluid for twenty-four hours after the morning meal. The urine samples of the second twelve-hour period are saved, and the specific gravities of the samples are determined. *In the normal subject the specific gravity of the urine will reach 1.026 or more, usually 1.032.* In hot weather the time is shortened to eighteen hours.

**SODEMAN-ENGELHARDT TEST.**<sup>39</sup> This test is similar to that of Addis and Shevky except that the period of dehydration is replaced by an injection of "posterior pituitary." No preparation is necessary. A preliminary urine specimen is obtained, after which 1 ml. of obstetrical or 0.5 ml. of surgical posterior pituitary is given subcutaneously. Urine specimens are collected one and two hours after the injection, and the specific gravity of each is determined. *The normal subject should concentrate to at least 1.023.* The results of this test are frequently unreliable because of too great variation in response, but if abnormal

ults are obtained, one of the other concentration tests may be performed to firm the findings.

**VOLHARD'S DILUTION CONCENTRATION TEST.**<sup>20</sup> After emptying the bladder, the subject drinks 1500 ml. of water within three-quarters of an hour. He remains in bed, and urine specimens are collected at half-hour intervals for the next four hours. The volume and specific gravity of each of these are measured. *The normal subject excretes 1500 ml. of urine within four hours, and the specific gravity of the urine may be decreased to 1.002. At the end of the four-hour period fluids are withheld for the remainder of the day. In the normal subject this results in a sharp decrease in the urinary volume, specific gravities of about 1.030 being obtained.*

**LUNDGAARD'S MODIFICATION OF THE VOLHARD TEST.**<sup>23</sup> The subject receives no water after midnight. He voids at 7 A. M., drinks a liter of water, then voids hourly until 11 A. M. *The normal subject voids at least a liter of urine in two to three hours, and a specific gravity of about 1.005 is reached. On a different day no voids are taken after midnight. A dry meal (consisting of 65 gm. of toast, 10 gm. of butter, 100 gm. of scrambled egg, 25 gm. of cream, and 15 to 20 gm. of jelly) is given at 7:30 A. M., and repeated at 10 A. M. and 11:40 A. M. Urine specimens are collected hourly from 7 A. M. to 3 P. M. In the normal subject the specific gravity of the urine reaches 1.025 to 1.030.*

**FISHBERG'S CONCENTRATION TEST.**<sup>17</sup> At 6 P. M. on the evening before the test the subject is given a meal including "considerable protein but no fluid; meat, potatoes, and other vegetables, and pie or a gelatin dessert." Nothing further is ingested until after the completion of the test. The bladder is emptied before retiring, and the urine is discarded. Upon arising, a specimen of urine is collected. The patient returns to bed, and another specimen is collected an hour later. The patient is now permitted to be ambulatory, and after an hour a third specimen is collected. *In the normal subject at least one specimen of urine will have a specific gravity of more than 1.022.*

**FISHBERG'S DILUTION TEST.**<sup>17</sup> The subject empties his bladder and consumes 1200 ml. of water within a half-hour. He remains in bed throughout the test, and urine specimens are collected at half-hourly or hourly intervals. *In the normal subject 1200 ml. of urine are eliminated in less than three hours. The specific gravity of the largest specimen is about 1.002.*

**CONCENTRATION TEST OF LASHMET AND NEWBURGH.**<sup>22</sup> After 10 P. M. of the day preceding the test no food or fluid other than a special diet is given. The latter consists of protein, 40 gm.; fat, 104 gm.; carbohydrate, 240 gm.; salt, 1 gm. During the day the specific gravity of the voided specimens is determined. *In the normal subject a specific gravity of 1.029 to 1.032 is reached.*

**CONCENTRATION TEST OF ISBERG AND NEWBURGH.**<sup>19a</sup> In this test the subject finishes his evening meal and eats and drinks nothing until the following noon. Urine collections are obtained at 8 and 10 A.M. and at noon, and the specific gravity is determined in each of these specimens. Under the conditions of this test *normal persons concentrate urine having a specific gravity of 1.025 or above; in persons with severe impairment of function the specific gravity is decreased to 1.014 and below.*

**QUANTITATIVE FORMULATION OF MAXIMUM SPECIFIC GRAVITY.** The simple determination of the maximum concentrating ability of the kidneys has an important disadvantage. As Alving and Van Slyke<sup>3</sup> pointed out, the concentration tests are important qualitatively, but fail as a quantitative measurement of renal function when the specific gravity of the urine becomes fixed at 1.010. By an empirically determined relationship, Corcoran and Page<sup>4</sup> have derived the formula

$$T = \frac{\text{Sp. Gr.} - 3.4}{2.58} \sqrt{UC}$$

where  $T$  is the functional tubular secretory mass in terms of percentage of mean normal,  $\text{Sp. Gr.}$  is "the value of the significant numerals of the measurement of specific gravity (3rd, 4th, and 5th decimal places)" as determined by the test of Addis and Shevky,<sup>4</sup> and  $UC$  is the urea clearance in per cent of normal. According to Corcoran and Page, the calculation of  $T$  makes it possible to obtain greater quantitative information from the concentration test.

**ALBARRAN TEST (EXPERIMENTAL POLYURIA).**<sup>5</sup> This test is generally performed in conjunction with ureteral catheterization for the estimation of individual kidney function. The patient abstains from food and drink for at least three hours. At the end of this period urine is collected from each kidney for a period of one-half hour. After this, 600 ml. of water are ingested and the urine is collected from each kidney for a period of an hour and a half. *In the normal kidney an increased secretion of urine appears within the first half-hour after water ingestion and reaches its maximum during the third half-hour. It then rapidly declines. The total amount of solids remains constant, although dilution proportionate to the increased volume of urine occurs.*

### TESTS DEPENDING ON URINARY VOLUME AND SPECIFIC GRAVITY

During the compensated stage of renal parenchymal damage the kidneys are able to maintain adequate excretion of nitrogenous waste products and to overcome loss of concentrating ability by means of polyuria. In other words, a given amount of solids is excreted in a large volume of relatively dilute solution rather than in a small volume of concentrated solution. Hence the detection of polyuria on a known intake suggests renal parenchymal disease.

**MOSENTHAL VOLUME-SPECIFIC GRAVITY TEST.**<sup>29</sup> This test is largely of historical interest. The patient is given no food or fluid other than the special diet described by Mosenthal. This is taken in the form of three meals daily, no food or fluid being taken between meals. Urine is collected at two-hour intervals throughout the day from 8 A. M. to 8 P. M. The entire night urine from 8 P. M. to 8 A. M. is then collected the next morning. Volumes and specific gravities are determined upon each specimen. *In the normal subject the specific gravities cover a range of at least 0.010, the night urine has a specific gravity of 1.018 or higher and a volume of 400 ml. or less, and the total volume of urine passed during the twelve-hour day period is three to four times as great as that of the twelve-hour night period.*

TESTS OF CONCENTRATION OF SPECIFIC SOLIDS

UREA CONCENTRATION TEST.<sup>24</sup> Fifteen grams of urea in 100 ml. of water ingested after the bladder has been emptied. The entire urinary specimen collected after one and two hours, respectively. The first specimen is discarded, the diuresis induced by the urea gives a misleading result. The concentration of urea in the second specimen is determined. *In the normal subject a concentration of 2 per cent or more will be found.*

XYLOSE CONCENTRATION TEST.<sup>18</sup> On an empty stomach and after voiding, the subject consumes 50 gm. of xylose in a small amount of lemonade. No more food is taken until the test is completed. Urine specimens are obtained at intervals of one, two and three hours after ingestion of the xylose. The urinary xylose is determined by the usual quantitative method for estimating sugar. In diabetic cases dextrose must be first removed by fermentation. *The normal subject is able to concentrate the xylose to 2.5 per cent within two hours."*

BLOOD CONSTITUENT TESTS

When renal failure progresses to a point where nitrogenous components of the blood can no longer be excreted at a rate that will maintain chemical equilibrium, these products begin to accumulate. This stage is characterized by the increase of many of the blood constituents to higher than normal values. The level of blood constituents may be misleading when taken alone, since extrarenal factors may affect them. However, in the presence of known renal damage, these measurements are probably the surest indication that waste products are being inadequately excreted.

CONCENTRATION OF NONPROTEIN NITROGEN BLOOD COMPONENTS. Table 189 gives the components in blood that serve as indicators of waste product retention, and their range of values in the normal subject.

TABLE 189  
NORMAL VALUES OF NONPROTEIN NITROGEN BLOOD COMPONENTS\*  
(Fishberg, 1939; Sunderman, 1945)

	Mg. per 100 ml.	
Blood urea nitrogen . . . . .	8.9	-15.2
Blood nonprotein nitrogen . . . . .	27.8	-39.4
Blood uric acid . . . . .	2.0	- 4.0
Blood creatinine . . . . .	1.0	- 2.0
Serum inorganic phosphorus . . . . .	3.2	- 4.3
Blood amino acid nitrogen . . . . .	5.0	- 8.0
Blood indican . . . . .	0.026-	0.085

\* See also Résumé of Chemical Composition of Blood, Chapter 23 (p. 186).

UREA RATIO. According to Mosenthal and Bruger,<sup>30</sup> the ratio of urea nitrogen to nonprotein nitrogen in the blood rises with impairment of renal function. The ratio is calculated by dividing the concentration of urea nitrogen in the blood by the concentration of nonprotein nitrogen in the blood, and multiplying the result by 100. *In the normal person the ratio value is 44 or less.*

CRYOSCOPY OF URINE.<sup>34</sup> Depression of the freezing point of urine roughly parallels the specific gravity. In the normal subject urine may be excreted which has a freezing point as low as minus 3.5° C.

### FOREIGN-SUBSTANCE EXCRETION TESTS

Although these tests were widely used in the past, their many disadvantages have caused them to be gradually abandoned in favor of more reliable procedures. In principle, they measure the rate of excretion of a known amount of foreign substance. It has been found, however, that the output of foreign substance can be varied by the amount of fluid available for excretion. Thus, with adequate fluid output, the test may be normal in the presence of renal parenchymal disease. The principal value of the tests today is in conjunction with cystoscopy when it is desired to estimate the individual function of each kidney.<sup>35</sup>

PHENOL RED (PSP) EXCRETION TEST.<sup>35</sup> The original test of Rowntree and Geraghty is conducted as follows: After the subject empties the bladder and consumes 250 ml. of water, 1 ml. of solution containing 6 mg. of phenolsulfonphthalein is injected intramuscularly (or intravenously). The subject empties the bladder seventy minutes and 130 minutes after the injection. The amount of phenolsulfonphthalein in each specimen is determined colorimetrically. *In the normal subject the first specimen contains 40 to 60 per cent of the dye, and the second specimen 20 to 25 per cent.* If the test is used in conjunction with ureteral catheterization, in the presence of unilateral renal disease, the normal kidney should excrete that part not eliminated by the diseased organ in addition to its own share.

FRACTIONAL PHENOLSULFONPHTHALEIN TEST. Chapman and Halstead<sup>36</sup> modified the previous test to give greater sensitivity. The subject empties the bladder and consumes 600 ml. of water. After thirty minutes 1 ml. of phenolsulfonphthalein solution is given intravenously. Urine is collected fifteen, thirty, sixty and 120 minutes after the injection. The fifteen-minute specimen is the most important, and is usually sufficient. *In the normal subject the fifteen-minute specimen contains 28 to 51 per cent of the dye, the thirty-minute specimen 13 to 24 per cent, the sixty-minute specimen 9 to 17 per cent, and the 120-minute specimen 3 to 10 per cent.*

METHYLENE BLUE EXCRETION TEST.<sup>1</sup> A solution of methylene blue is injected intramuscularly or intravenously. *In the normal subject the dye appears in the urine in about thirty minutes by the former route, and in about five minutes by the latter.* The test is of value in conjunction with cystoscopy.

INDIGO-CARMINE EXCRETION TEST.<sup>42</sup> As in the methylene blue test, qualitative estimation of individual kidney function during cystoscopy is the principal use of this test. Four milliliters of a 4 per cent solution of the dye are injected intramuscularly or intravenously. *In the normal subject the dye appears at the ureteral orifice after ten to fifteen minutes by the former route, and after three to five minutes by the latter.*

SULFATHIAZOLE EXCRETION TEST.<sup>20</sup> One-tenth gram of sodium sulfathiazole in 10 ml. of distilled water is given intravenously. Specimens are collected after one and two hours. The total amount of the drug in each specimen is determined

the usual colorimetric method. *In the normal subject over 20 per cent of the is excreted within two hours.*

### BALANCE TESTS

These tests measure the rapidity with which the kidneys can excrete an excess of one of the normal urinary constituents.

**UREA BALANCE TEST.**<sup>17</sup> The subject is put on a fixed diet for three days before the test. The following diet is recommended: 750 ml. of milk, 4 eggs, 100 gms. of salt-free butter, 30 gm. of flour, some fruit, sugar and tea. During this time the total daily urinary nitrogen excretion is carefully measured to establish the expected daily urinary nitrogen excretion on the diet given.

In performing the test the patient is given 20 gm. of urea in a small amount of milk in addition to the fixed diet. The total daily urinary nitrogen excretion is measured for three days after the ingestion. *The normal subject will excrete an amount of urinary nitrogen equivalent in amount to 20 gm. of urea in addition to the expected daily urinary nitrogen excretion in less than two days.*

**CHLORIDE BALANCE TEST.**<sup>17</sup> This test is conducted in the same manner as the urea balance test, except that analyses for urine chloride are made for three days before and three days after the ingestion of 10 gm. of sodium chloride. *In the normal subject the excess chloride is excreted in less than two days.*

**CREATININE BALANCE TEST.**<sup>25</sup> Urine is collected for a one-hour period and three labeled specimen No. 1. One-half gram of creatinine is given intravenously, and two more urine specimens are collected at the end of one and two hours. These are labeled No. 2 and No. 3, respectively. The creatinine concentration and the total creatinine content of each of the three urinary specimens is determined. *In the normal subject the total creatinine content of specimen No. 2 is about three times that of specimen No. 1, and the creatinine concentration is about twice that of specimen No. 1. In specimen No. 3 the total content and concentration of creatinine show a marked increase as compared with specimen No. 2.*

### MISCELLANEOUS TESTS

**ACID-ALKALI TEST.**<sup>34</sup> This test depends on the fact that fixation of pH as well as of other functions tends to occur in the diseased kidney. Twenty drops of 10 per cent dilute hydrochloric acid in 300 to 400 ml. of water are ingested. After two hours a urine specimen is collected. Fifty milliliters of 4 per cent sodium bicarbonate solution are then given intravenously, and another specimen of urine is collected a few minutes later. *In the normal subject the first specimen has a pH of about 4.0; the second specimen shows a rapid rise in pH.*

**PHLORHIZIN TEST.**<sup>2</sup> Phlorhizin inhibits reabsorption of glucose in the proximal tubules, probably by inhibiting the action of phosphorylase, the preliminary phosphorylation of glucose being necessary for reabsorption. The expected degree of glycosuria does not appear in renal disease, however. Five milligrams of phlorhizin are given subcutaneously. *In the normal subject a total of 0.5 to 2.5 gm. of glucose is eliminated within a four-hour period.*

**ALIZARIN TEST.**<sup>31</sup> According to its proponents, this test involves a protective colloid reaction on the part of colloidal substances present in the diseased kid-

ney. A small drop of 1 per cent sodium alizarin sulfonate in doubly distilled water is mixed on a clean slide with a large drop of fresh urine. *In the normal subject a coarse, light-red precipitate appears in a few seconds.* The precipitate does not appear in the presence of renal parenchymal disease. Salt-poor urines are said to give a false positive reaction.

**DIAZO TEST.**<sup>19</sup> This test probably depends upon the presence of increased concentration of indoxyl compounds in the blood. Two milliliters of 95 per cent alcohol are added to 1 ml. of plasma or serum and the mixture is centrifuged. To 1 ml. of the supernatant fluid 0.25 ml. of the Van den Bergh reagent is added. The mixture is boiled for thirty seconds. *In the normal serum there is either the development of a faint pink color or no color change at all.* A green color appears with the addition of 40 per cent sodium hydroxide. In the uremic subject, an orange-buff color appears, followed by a cherry-red color when sodium hydroxide is added.

**HIPPURIC ACID SYNTHESIS TEST.**<sup>21</sup> A fraction of ingested benzoic acid may be converted to hippuric acid in the kidney. The larger fraction is probably conjugated in the liver, however. In renal disease there may be some reduction in the rate of hippuric acid excretion. Whether this is caused in part by a reduction in the rate of hippuric acid synthesis is questionable. The test is made as follows: 2.4 gm. of sodium benzoate in 100 ml. of water are ingested after the subject has been placed on a fruit-free diet for twenty-four hours. *In the normal subject 95 to 100 per cent of the ingested substance is excreted as hippuric acid within three hours.*

TABLE 190

## RÉSUMÉ OF RENAL FUNCTION TESTS

<i>Test</i>	<i>Normal Values</i>
Inulin (or mannitol) clearance	120 to 130 ml. of plasma cleared per minute
Diodrast (or hippuran) clearance (Renal Blood Flow)	520 to 1560 ml. of plasma cleared per minute
Tubular excretory mass index (diodrast)	36 to 72 mg. of diodrast iodine per minute
Urea clearance	Maximal: 75 ml. of blood cleared per minute (100 per cent) Standard: 54 ml. of blood cleared per minute (100 per cent) Average normal function: 80 to 120 per cent
Exogenous creatinine clearance	152 ml. of blood cleared per minute (average)
Endogenous creatinine clearance	125 ml. of blood cleared per minute (average)
Ambard constant	0.07
McLean's index	100
Addis' ratio	35 to 60
Volhard's (dilution)	Excretion of 1500 ml. of urine, specific gravity 1.002 in 4 hours
Volhard's (concentration)	Specific gravity of 1.030
Lundsgaard's (dilution)	1 liter of urine, specific gravity 1.005, voided in 2 to 4 hours
Lundsgaard's (concentration)	Specific gravity 1.025 to 1.030
Fishberg concentration	Specific gravity 1.022
Fishberg dilution	1200 ml. of urine, specific gravity 1.002, voided in 3 hours
Isberg and Newburgh concentration	Specific gravity 1.025 and above
Lashmet and Newburgh concentration	Specific gravity 1.029 to 1.032
Addis and Shevky concentration	Specific gravity over 1.026

TABLE 190—*Continued*

man-Engelhardt	Specific gravity over 1.023
rran	Increased urinary secretion within one-half hour
enthal	Specific gravity range of 1.010; night urine: specific gravity 1.018, volume 400 ml.; day urine: 3 to 4 time volume of night urine
concentration	Concentration of urea in urine to 2 per cent
se concentration	Concentration of xylose in urine within 2 hours, 2.5 per cent
d amino acid nitrogen	5.0 to 8.0 mg. per 100 ml.
d urea nitrogen concentration ✓	8.9 to 15.2 mg. per 100 ml.
d NPN concentration ✓	27.8 to 39.4 mg. per 100 ml.
d creatinine concentration ✓	1 to 2 mg. per 100 ml.
d uric acid concentration	2 to 4 mg. per 100 ml.
m inorganic phosphorus concentration	3.2 to 4.3 mg. per 100 ml.
d indican concentration	0.026 to 0.085 mg. per 100 ml.
a ratio (urea N X 100/NPN) ✓	44 or less
excretion	40 to 60 per cent of dye in first specimen; 20 to 25 per cent in second
ctional PSP excretion	28 to 51 per cent dye in first specimen
ethylene blue excretion	Dye appears in 5 minutes when injected intra- venously
igo-carmine	Dye appears in 3 to 5 minutes when injected intravenously
athiazole excretion	20 per cent of dye excreted in 2 hours
a balance ✓	Excretion of excess urea in less than 2 days
loride balance	Excretion of excess chloride in less than 2 days
eatinine balance ✓	Creatinine concentration in urine doubles in 1 hour
d-alkali ✓	After acid ingestion urinary pH is 4.0. After intravenous bicarbonate urinary pH shows rapid rise
lorhizin	0.5 to 2.5 gm. of glucose eliminated in 4 hours
zarin	Coarse red precipitate in a few seconds
azo	Faint pink color, becoming green with NaOH
yosecopy	Maximum freezing point depression of 3.5°C.
opuric acid synthesis ✓	95 to 100 per cent of benzoic excreted as hip- puric acid in 3 hours

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## Chapter 40

# THE URETER, BLADDER AND URETHRA

## URETER

THE URETER is a hollow musculomembranous organ which conducts the urine from the renal pelvis to the bladder. It is a retroperitoneal structure, coming down over the anterior surface of the psoas muscle, crossing over the iliac vessels at the brim of the pelvis and following the curvature of the true pelvis downward to and entering the base of the bladder.

**LENGTH.** The normal ureter in the adult is stated to be 28 to 34 cm. long,<sup>9</sup> to 32 cm.,<sup>14</sup> 25 to 30 cm.,<sup>8</sup> and 28 to 34 cm.<sup>1</sup> The right ureter is 1 to 2 cm. shorter than the left.

**DIAMETER.** The diameter of the ureteral lumen ranges from 1 to 10 mm.,<sup>4</sup> to 10 mm.,<sup>11</sup> or 1.5 to 7 mm.,<sup>6</sup> varying greatly from one part of the ureter to other.

TABLE 191  
AVERAGE DIAMETER OF URETERAL LUMEN  
(Eisendrath and Rolnick, 1938)<sup>4</sup>

<i>Location</i>	<i>Millimeters</i>	<i>By Bougie (French)*</i>
Ureteropelvic junction.....	2	6
Lumbar spinal.....	10	30
At iliac crossing.....	4	12
Pelvic spindle.....	4-6	12-18
Juxtavesicle.....	1-5	3-15
Intramural.....	3-4	9-12

\* French is 3 times the diameter of the bougie, measured in millimeters.

The characteristic narrow parts of the ureter which are of clinical importance are at the ureteropelvic junction, the junction of the lower and middle thirds (where the ureter crosses the iliac vessels), and the intramural portion.

The ureters transport the urine to the bladder by a series of peristaltic waves produced by muscular contractions of the ureteral wall. The two ureters do not expel urine simultaneously and are completely independent of each other regardless of the degree of filling of the bladder.<sup>1</sup> The ureteral contractions may be rhythmic or arrhythmic, coming in groups or irregularly with intervals of long or short duration.

The ratio of contraction ranges from once every two to three minutes to one or six times a minute,<sup>19</sup> or from one to five contractions per minute.<sup>8</sup> The amplitude and speed of the peristaltic contraction vary from one part of the ureter to the other. The greatest amplitude is at the midureter, and the average speed was found to be 18.3 mm. per second in the upper third, 15.4 mm. per second in the middle third, and 13.3 mm. per second in the lower third.<sup>8</sup>

## BLADDER

The bladder is a hollow muscular organ which acts as a reservoir for the urinary tract and whose function is to receive the urine from the ureter, hold it for a time and expel it to the outside via the urethra. The bladder wall is made up chiefly of muscle, the detrusor urinae, which acts as a unit in exerting pressure from all sides on the vesicle contents during the act of voiding.

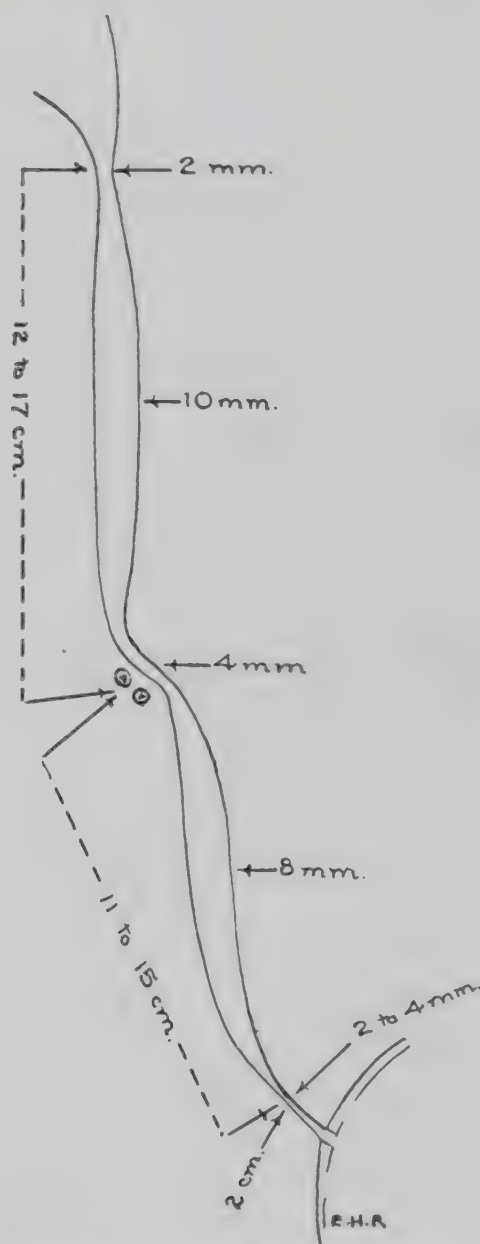


Fig. 89. Average diameters of the ureteral lumen and the lengths of its three divisions. (Pelouze: Office Urology.)

The mucosa of the bladder is formed by a specialized epithelial layer, the transitional cell epithelium. This epithelial layer is separated from the muscular part of the bladder wall by a layer of loose cellular tissue present in all regions except the trigone, where the epithelial lining is continuous with that of the ureters and the renal tubules above and the urethra below. When the bladder

empty it lies in loose folds, except at the trigone, where it remains smooth and flat. The transitional epithelium of the bladder is up to 2 mm. thick when contracted and becomes very thin when the bladder is distended.<sup>3, 4, 7</sup> There is appreciable absorption through the bladder mucosa.<sup>7</sup> There are no glands in the normal bladder epithelium.

The ureteral orifices are symmetrically placed in the base of the bladder, forming the corners of the trigone, which is shaped like an equilateral triangle with its apex at the vesicle orifice. The base of the triangle measures 3.5 to 5 cm. when the bladder is distended and 2.5 cm. when it is contracted.

**SHAPE AND POSITION.** The bladder is an extraperitoneal organ located in the adult in the anterior part of the true pelvis. When distended, the bladder projects well up into the abdomen. During the prenatal period, at birth and in early childhood it is primarily an abdominal organ, lying just beneath the abdominal wall, and cylindrical to pyramidal in shape. During the growth period the bladder gradually descends into the true pelvis, becoming at that time more ovoid. The bladder lies lower in the pelvis in women than in the male.

The relations of the bladder to the peritoneum are important. The peritoneum envelops the superior and posterior aspects of the bladder, to which it is loosely adherent, except for an area 3 to 5 cm. in diameter at the vertex, where it is closely and firmly attached.<sup>4, 9</sup>

The form and capacity of the normal adult bladder show great variation from one person to another. It may vary from an almost round form with a capacity of only 150 ml. to the more ovoid bladder which will comfortably contain 250 to 300 ml.<sup>4</sup> When empty, the bladder assumes the shape of a flattened tetrahedron. In men the greatest diameter is in the sagittal plane, whereas in women it is widest in the transverse plane.<sup>15</sup>

The bladder capacity, as noted in most instances, is that at which the first desire to void is felt and ranges from 150 to 300 ml.<sup>4, 14</sup> Simons<sup>16</sup> reports it to be 150 to 225 ml. The actual physiologic volume is at least 100 per cent greater than that at which the first desire to void is noted. Under pathologic conditions the bladder may be found to contain volumes of 3000 ml. or more. The normal bladder in men has an actual capacity of from 150 to 200 ml. less than that in normal women.<sup>15</sup>

**CYSTOMETRIC VALUES.** As the bladder fills, it accommodates itself gradually to the increased volume, so that up to the point where a desire to urinate is noted the intravesicular pressure remains small. It ranges between 4 and 6 mm. of mercury.<sup>16</sup> According to Simons,<sup>16</sup> the normal tonus of the internal sphincter is 15 mm. of mercury and of the external sphincter, 23 mm. of mercury. At the time of voiding, the intravesicular tension rises to from 8 to 15 mm. of mercury.<sup>7</sup> Campbell<sup>2</sup> states that in the normal adult the first desire to void is noted at a volume of 240 to 260 ml. of water and that the intracystic pressure at that time is 15.5 to 16 cm. of water. He did cystometric studies on twenty-seven physiologically normal children between the ages of four and twelve years and found that the first desire to void was noted at from 80 to 280 ml. of water, at which time the intravesicular pressure ranged from 8 to 51 cm. of water.

The volume at the point of imperative urination was found to range from 120 to 400 ml. of water, with 12 to 92 cm. of water pressure. Muschat and his co-workers<sup>13</sup> did cystometric studies on twenty-five normal adults (see Table 192).

TABLE 192  
THE THREE CYSTOMETRIC FACTORS  
(Muschat et al., 1937)<sup>13</sup>

	Average Values		
	Normal	Hypotonic	Hypertonic
First desire to void.....	150-250 cc.	Over 250 cc.	Under 150 cc.
Pressure curve.....	Gradually rising	Low	High
Maximal voluntary pressure.....	60-80 mm.	Under 60 mm.	Over 80 mm.

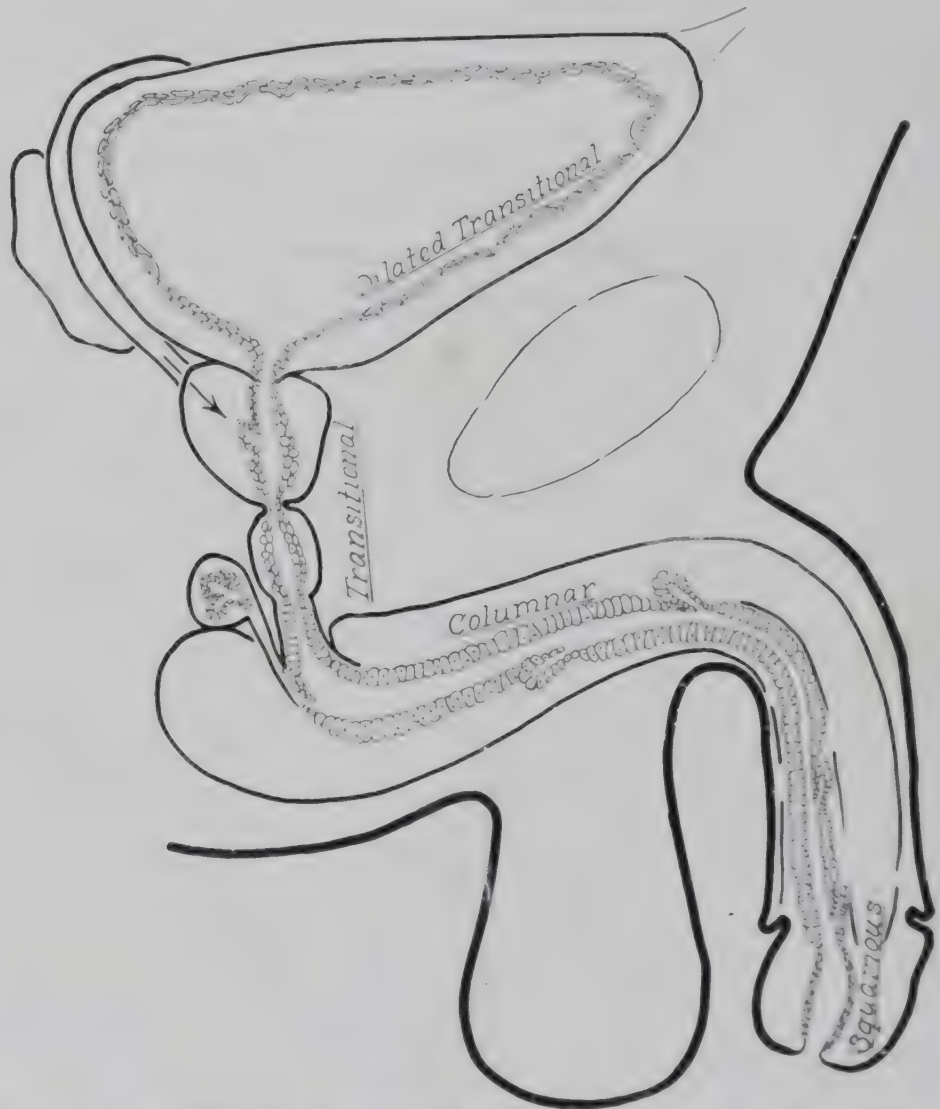


Fig. 90. Diagram illustrating the locations of the various types of mucous membrane in the male urogenital tract. All the channels leading from the main tract are lined by columnar cells. (Pelouze: Office Urology.)

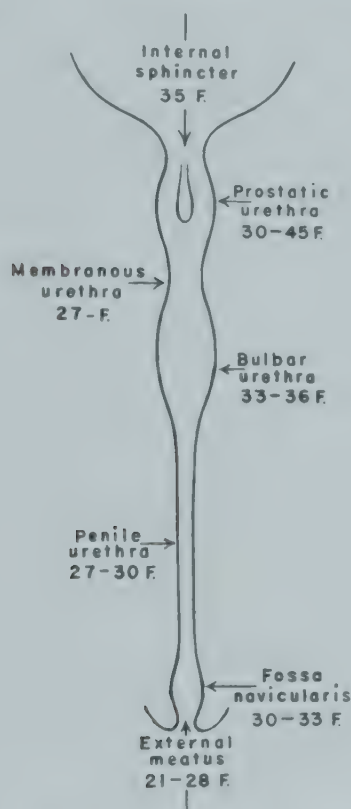
## URETHRA

The urethra is an epithelial-lined tubular structure which extends from the internal urethral orifice at the bladder to the urinary meatus.

## MALE URETHRA

In men the urethra is part of both the urinary and genital system, serving to carry and expel the urine and the seminal fluid. In the relaxed state it forms a gentle or S-shaped curve.

It is 15 to 20 cm. in length. Except during the passage of urine or semen, it is a collapsed tube forming a transverse slit with its upper and under surfaces



91. Diagram showing the average calibers of the various portions of the urethra. (Pelouze: Office Urology.)

contact, except at the external orifice, where it forms a vertical slit, the urinary meatus.<sup>9-14</sup> The caliber of the normal urethra varies greatly from one part to another.

The urethra is divided into the posterior or *prostatic urethra*, the *membranous urethra* and the anterior or *pendulous urethra*. The posterior urethra extends from the bladder to the triangular ligament. It is the widest part of the urethra and is 2 to 3½ cm. long.<sup>15</sup> It is surmounted by the prostate and is the site of the entrance into the urethra of the seminal ducts as well as the ducts of the prostatic gland. It is lined by transitional epithelium which extends into the membranous urethra from the bladder.

In the midline of the floor of the *posterior urethra* is a longitudinal crest, the verumontanum, a spongy glandular mass covered by mucous membrane, the verumontanum.

McCarthy and his associates<sup>10</sup> state its dimensions as 9 by 3 by 3 mm. Another study of thirty-eight specimens revealed its length to vary from 7 to 12 mm. (average, 9.0 mm.), and its breadth to range from 3 to 6 mm. (average, 4.0 mm.).<sup>11</sup> In the center of the verumontanum is a depression or sacculation parallel with the urethral floor, the prostatic utricle or sinus pocularis, which is the vestigium of what, in women, becomes the uterus. Its size varies considerably. In twenty-three cases its length was 4 to 19 mm. (average, 9.8 mm.), and its breadth ranged from 1 to 6 mm. (average, 2.5 mm.).<sup>7, 11</sup> There is no apparent correlation between its size and the person's age.<sup>12</sup> The ejaculatory ducts pass through the verumontanum and open at its apex, usually at each side of the utricle.<sup>10, 11</sup>

TABLE 193  
LENGTH OF PROSTATIC URETHRA\*  
(Barnes, 1943)<sup>1</sup>

External sphincter to verumontanum:	
Greatest.....	17 mm.
Least.....	7 mm.
Average.....	10.7 mm. (1 cm.)
Verumontanum to bladder neck:	
Greatest.....	21 mm.
Least.....	10 mm.
Average.....	17.1 mm. (1.7 cm.)
External sphincter to bladder neck:	
Greatest.....	38 mm.
Least.....	25 mm.
Average.....	29.5 mm. (3 cm.)

\* Ten normal specimens measured.

The *membranous urethra* is the shortest and narrowest part of the urethra. It perforates the triangular ligament and is completely surrounded by the cut-off muscle, forming the external sphincter. No glandular elements enter this part of the urethra. Its anterior wall measures 2 cm. in length, and the posterior wall, 1.25 cm.<sup>9</sup>

The *anterior urethra* is the longest part of the urethra. It is about 6 mm. in diameter and 15 cm. in length. The opening at the distal end, the meatus, has the form of a ventricular slit and is 5 to 6 mm. in length. Cowper's, or the bulbo-urethral, glands enter into the posterior part of the anterior urethra, and the epithelium of this part contains the urethral glands, or glands of Littre.

The length of the urethra and the development of the glands increase with age. Symington<sup>18</sup> noted the length to be 4.5 to 6 cm. in a male child one to six days old, 6.2 cm. at three and one-half months, 7 cm. at six months, 8.2 to 9.4 at five years, and 10 to 11½ cm. at twelve years of age.

The bulbo-urethral glands (Cowper's glands) are two small, rounded bodies about the size of a pea which are located behind and lateral to the membranous part of the urethra. Each gland has a single excretory duct, 2.5 cm. long, which opens by a minute orifice on the floor of the anterior urethra about 2.5 cm. in front of the triangular ligament. Its secretion is a clear mucous material rich in albumin. In the adult the gland gradually decreases in size with advancing age.\*

## FEMALE URETHRA

The female urethra consists of a narrow membranous canal extending from the internal urethral orifice, which is located on a level with the upper margin of the symphysis pubis, to the urethral meatus, located in the vulva about 2.5 cm. behind the glans clitoris. It is 34 to 38 mm. in length.<sup>17</sup> The urethra is slightly curved anteriorly, especially in its proximal third. The caliber of the urethra ranges from an 18 to 30 French bougie (6 to 10 mm.) with an average of 26 (8.6 mm.) French bougie.<sup>5, 17</sup>

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## Chapter 41

### URINE

#### PHYSICAL CHARACTERISTICS

**APPEARANCE.** Freshly voided normal urine is clear and transparent. It may be turbid after a large meal rich in proteins or vegetables.

On standing and on cooling it may become cloudy, owing to the presence of mucus and the formation of amorphous and crystalline substances. If the urine is acid, a pink or reddish sediment may appear because of amorphous urates. In alkaline urine a white sediment of amorphous and crystalline phosphates may occur.

**VOLUME.** *Normal adults excrete 800 to 1600 ml. of urine per day. Children six to twelve years of age excrete about one-half that amount, and those from one to six years of age about one-fourth.*<sup>41</sup>

The volume of night urine is less than that voided during the day. The ratio in normal persons may be expressed as N:D::1:2, 3 or 4.

Kilduffe<sup>35</sup> considers volumes over 2000 ml. as polyuria and under 600 ml. as oliguria. According to Addis and Oliver<sup>2</sup> the twelve-hour volume of urine in normal persons may range from 381 ml. when fluids are restricted to 7716 ml. when large amounts of water are taken. The volume of urine that is excreted may obviously be greatly modified and influenced by the external environment.

TABLE 194  
NORMAL VOLUME OF URINE IN CHILDREN ACCORDING TO AGE  
(Kolmer and Boerner, 1945)<sup>37</sup>

Age	Volume (Ml./24 Hours)
1 and 2 days.....	15 to 60
3 to 10 days.....	100 to 300
10 days to 2 months.....	250 to 450
2 months to 1 year.....	400 to 500
1 to 3 years.....	500 to 600
4 to 8 years.....	600 to 1000
9 to 15 years.....	800 to 1400
Over 15 years.....	1000 to 1600

**ODOR.** Fresh urine has a characteristic aromatic odor, which may be due to a substance called "urinod" or to volatile acids. Certain foods and drugs may affect the odor.

**COLOR.** Normally, urine is yellow, the intensity of the yellow being usually dependent upon the concentration of urinary constituents. Pigments, chiefly urochrome, give the urine its characteristic color. Traces of urobilin, urobilinogen and porphyrins may also contribute to the color. It should be noted that urobilinogen is a colorless compound; it therefore contributes to the color of urine only indirectly—i. e., when converted into urobilin.

The excretion of urinary pigment in normal persons is apparently constant day to day under usual conditions, and appears to be the product of endogenous metabolism.<sup>18-23</sup> It is increased by fasting, administration of acids, with increased metabolism.

Urine which is otherwise normal may vary in color when certain drugs are tested (Table 195).

TABLE 195  
EFFECT OF DRUGS ON COLOR OF URINE  
(Kilduffe, 1937)<sup>35</sup>

<i>Drug</i>	<i>Color Change Produced</i>
Analgen.....	Blood red (after large doses or prolonged use)
Beta-naphthol.....	After small doses, olive green; after large doses, reddish yellow
Bromoform.....	After large doses, dark green
Carbolic acid (phenol).....	Dark green turning to black on standing
Cascara sagrada.....	Dark, reddish yellow
Methylene blue.....	Various shades of green
Naphthalene.....	Dark gray
Phenocol and its salts.....	Reddish dark gray turning blackish on exposure to air
Phenolphthalein.....	Pinkish-red <i>when urine is alkaline</i>
Pyramidon.....	Salmon-red to cherry-red
Pyridium.....	Burgundy red
Rhubarb.....	Yellow to dark reddish-yellow (due to the presence of chrysophonic acid)
Salol.....	Dark green; after prolonged use, black
Santonin.....	Deep yellow
Senña.....	Same as rhubarb
Sulfonal (sulfonmethane).....	Dark red because of the presence of hemato-porphyrin
Thalline.....	Yellow changing to dark green to dark gray
Tetronal.....	Same as sulfonal
Trional.....	Same as sulfonal
Uva ursi.....	Olive-green passing through various shades of blue

**SPECIFIC GRAVITY.** The specific gravity of the urine of normal persons is directly proportional to the concentration of solids dissolved in it, the output of which is normally influenced by body weight, diet, exercise, metabolism and age.

*The specific gravity of urine obtained over a twenty-four-hour period normally ranges from 1.016 to 1.022 at room temperature, and is inversely proportional to the volume excreted.* Normal persons on a high intake of fluid may excrete urine with a specific gravity as low as 1.001, and on a low intake of fluid as high as 1.030 or more.

The specific gravity of urine of the newborn (day of birth) ranges from 1.004 to 1.019.<sup>70</sup>

For the study of specific gravity of the urine in relation to renal function, see Chapter 39.

**REACTION (pH).** The hydrogen ion concentration may range from a pH of 4.6 to 8.0 at room temperature. The average reaction of the total twenty-four-hour output is pH 6.2. The total titratable acidity of urine collected over a

period of twenty-four hours is usually between 200 and 400 ml. of N 10 acid, but may vary from 100 to 600 ml.

Many factors, such as rate and depth of pulmonary ventilation, drugs and emotional states, affect the reaction of the urine of normal persons. Urine becomes alkaline on standing, owing to the conversion of urea into ammonia. In slightly alkaline urine the amount of carbon dioxide may be appreciable, and its tension is close to 40 mm. Therefore, the pH may be increased slightly upon standing, if precautions are not taken to keep carbon dioxide in the system.

CHEMICAL COMPOSITION

The composition of urine is influenced by many factors, among which are physical activity, diet, quantity of fluid intake, drugs, environmental temperature, humidity, posture, mental excitement, age, weight and sex.

Table 211 lists the chemical components usually present in urine, together with the amount excreted in twenty-four hours.

TOTAL SOLIDS. Approximately 60 gm. of total solids are excreted in the urine daily. *The normal range is 55 to 70 gm.* These solids are composed of about equal parts of organic and inorganic substances.<sup>10, 28</sup>

NITROGENOUS SUBSTANCES. The amounts of most of the nitrogenous substances excreted in the urine depend upon the type of diet and protein intake. Elimination of creatinine, however, is relatively constant even with a wide variation in protein intake.

TABLE 196  
DAILY EXCRETION OF NITROGENOUS SUBSTANCES IN NORMAL HUMAN URINE  
(Everett, 1946)<sup>20</sup>

	Grams	Grams N	Per Cent of Total N	Approximate Concentration by the Kidney
Total nitrogen.....	...	12.5*	100	
Urea.....	22	10.5	85	60
Creatinine.....	1.3	0.55	4.5	70
Ammonia.....	0.7	0.57	4.5	
Total amino acids.....	...	0.5	4.0	
Free amino acids.....	...	0.1	0.8	2
Uric acid.....	0.7	0.23	2	20
Other purines.....	0.02			
Hippuric acid.....	0.7	0.055	0.4	
Imidazole derivatives.....	0.3			
Phenols.....	0.2	...	...	10
Glycocyamine.....	0.03	0.01		
Allantoin.....	0.03	0.01		
Indican.....	0.01	...	...	3

\* In addition, 1.3 gm. are excreted in the feces and 0.7 gm. by the skin.

UREA. The amount of urea excreted in the urine in twenty-four hours is 15 to 35 gm.<sup>20, 49</sup>

About 80 to 90 per cent of the total nitrogen found in normal urine is present as urea. The output usually varies directly with the protein intake. It may be noted that with low-protein diets the urea nitrogen percentage of the total nitrogen in the urine may be less than 80.

**CREATININE.** Creatinine is derived from endogenous sources; therefore its daily excretion is little, if at all, influenced by diet. Its excretion is also not influenced by exercise or by variations in the urine volume. Because of this latter relationship the daily excretion of creatinine is often used to check the accuracy of twenty-four-hour collections of urine. It is one of the so-called "nonthreshold" substances in the urine. *The daily range of excretion of creatinine for normal adults is from 1.2 to 1.7 gm.<sup>28</sup>* In thirty-four boys fourteen to nineteen years of age the twenty-four hour preformed creatinine ranged from 1.022 to 1.985 gm.<sup>42</sup>

The "*creatinine coefficient*" represents the ratio of the daily excretion of creatinine in milligrams to the body weight in kilograms. This averages 20 to 36 in normal men and 14 to 22 in women; in terms of milligrams of *creatinine nitrogen* these values are equivalent to 7.5 to 10 for men and 5 to 8 for women. The difference in values noted between men and women may not be due directly to sex, and is probably related to muscle mass.

TABLE 197  
EXCRETION OF CREATININE AND CREATINE BY NORMAL INFANTS  
(Marples and Levine, 1936)<sup>48</sup>

Number of Cases	Age in Months	Creatinine Nitrogen (Mg./Kg. in 24 Hrs.) Average	Creatine Nitrogen (Mg./Kg. in 24 Hrs.) Average	Total Creatinine plus Creatine Nitrogen (Mg./Kg. in 24 Hrs.) Average	Investigator
8.....	1½-13	4.63	...	...	Rougichitch (1926)
9.....	1-22	4.80	...	...	Rougichitch (1926)
6.....	5-12	4.45	5.68	10.04	Rougichitch (1926)
9.....	2-8	4.28	...	...	Daniels and Hejinian (1929)
5.....	1½-7	4.93	3.89	8.86	Marples and Levine (1936)

**CREATINE.** Creatine is formed in small amounts in the urine of normal infants and children up to the age of puberty (see Table 198). The amount is normally influenced by protein in the diet.

Creatine is always present in normal pregnant women and intermittently in nonpregnant women. There is no consensus whether the presence of creatine in the urine is related to menstruation. Small amounts of creatine may be found in the urine of men (Table 198).

**AMMONIA.** The amount of ammonia excreted in the urine during twenty-four hours usually varies with the protein intake. *Normally, ammonia nitrogen in the urine is about 5 per cent of the total nitrogen.* An increase to more than

URINARY SYSTEM

TABLE 198  
CREATINURIA IN NORMAL PERSONS  
(Albanese and Wangerin, 1944)<sup>4</sup>

Age Group in Years	Age Limit of Creatinuria (in Years)	Number of Subjects Studied	Number of Subjects with Creatinuria	Creatine Excreted per Day (Mg.)	Diet	Investigator
8-17.....	17	3	3	90-150	Normal	Folin and Denis
1-19.....	13	19	13	25.3/100 cc.	Normal	Rose
14-19.....	19	81	35	17-117	Normal	Light and Warren
20-34.....	34	15	14	0-196	Normal	Taylor and Chaw
21-58.....	58	148	108	0-428/l.	Chinese	Djen and Platt
19-30.....	30	96	97	92-1200	Normal: Carbo- hydrate varied	Hobson
20-55.....	55	15	11	0-200	Normal	Wang
19-35.....	35	31	31	0-796	Various	Albanese and Wangerin
19-35.....	35	14	14	184-352	Normal	
19-25.....	25	9	9	202-358	Vegetables, fat and carbohy- drate	
19-25.....	25	8	8	17-796	Casein digest, fats,vegetables, carbohydrates	
19-23 (Females)	23	4	4	61-354		

10 per cent is considered abnormal.<sup>35</sup> The urinary excretion of ammonia is 0.5 to 1.1 gm. daily;<sup>10</sup> 0.3 to 0.7 gm. daily.<sup>49</sup>

AMINO ACIDS. Small amounts of amino acids are normally excreted in the urine in the free state as well as in the conjugated and peptide forms. Table 199 gives the normal urinary excretion of "free" and "combined" amino acids by microbiological methods.

TABLE 199  
URINARY EXCRETION OF "FREE" AND "COMBINED" AMINO ACIDS BY 18 SUBJECTS ON NORMAL  
DIETS (REPORTED AS MILLIGRAMS PER 24 HOURS)  
(Hier, 1948)<sup>30</sup>

	Free		Total		Combined		Per Cent Combined Form of Total	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Arginine.....	11.0- 36.2	21.3 ± 6.9	12.2- 45.0	23.7 ± 7.9	0- 13.8	6.6	0- 52.9	24.2
Aspartic acid...	0- 23.6	1.3 ± 0.6	87.4-258.8	164.5 ± 46.7	82.7-258.8	163.2	82.1-100	99.2
Cystine.....	45.2-138.0	87.7 ± 25						
Glutamic acid...	0- 63.7	35.8 ± 19.2	102.4-769.5	351.4 ± 151.4	72.6-708.7	315.6	79.0-100	89.5
Histidine.....	60.3-378.0	188.3 ± 99.2	65.4-438.8	203.3 ± 101.1	5.1-123.2	40.5	1.8-34.5	11.9
Isoleucine.....	0- 20.1	5.9 ± 4.5	11.8- 33.4	20.3 ± 5.5	3.9- 30.3	14.4	18.3-100	71.0
Leucine.....	3.8- 18.5	9.6 ± 3.3	11.9- 40.0	21.2 ± 6.6	3.5- 29.6	12.3	29.4- 81.8	55.6
Lysine.....	18.2- 88.2	33.6 ± 16.9	35.6-166.0	73.2 ± 29.4	15.4- 77.8	43.0	23.4- 74.8	57.1
Methionine.....	4.1- 13.5	7.8 ± 2.9	4.1- 15.0	8.6 ± 2.8	0.5- 6.3	2.3	4.7- 60.5	24.6
Phenylalanine...	7.5- 34.0	16.4 ± 7.1	10.3- 45.4	23.3 ± 7.9	3.1- 16.9	8.4	14.4- 66.6	35.2
Proline.....	3.7- 14.8	8.5 ± 2.9	23.1- 62.1	42.8 ± 12.9	18.1- 54.4	34.3	65.1- 89.0	80.2
Threonine.....	12.4- 49.5	24.4 ± 10.9	14.8- 84.4	53.8 ± 19.5	18.8- 53.8	31.3	41.7- 67.9	58.0
Tryptophane...	8.5- 56.0	24.6 ± 11.3	11.2- 86.1	41.4 ± 17.5	0.6- 28.3	18.4	1.3- 71.8	41.9
Tyrosine.....	10.5- 43.9	20.8 ± 1.7	23.4-100.3	52.5 ± 18	5.9- 60.3	31.7	25.2- 75.1	60.4
Valine.....	0- 7.5	4.5 ± 2.2	11.0- 30.0	19.8 ± 5.6	6.1- 28.2	15.3	55.4-100	77.3

**PURINES.** Normal persons excrete 0.5 to 1.0 gm. of uric acid daily. This amount is subject to wide variations. On a purine-free diet the uric acid output may be 0.1 to 0.5 gm. per day, whereas on a high purine diet it may be as much as 2 gm.

**URIC ACID.** Uric acid is excreted in urine chiefly as a monourate. The output largely depends on the purine content of the diet. From 0.5 to 1.0 gm. is normally excreted in twenty-four hours. In the newborn infant the excretion may be as much as 7 to 8 per cent of the total nitrogen.

**ALLANTOIN.** Larson<sup>28</sup> found minute amounts in the urine of normal persons. The amounts excreted were from 5 to 12 mg. per liter and as much as 25 mg. in twenty-four hours.

From 15 to 60 mg. of purine bases are excreted in twenty-four hours. These include adenine, paraxanthine and perhaps guanine.

**PYRIMIDINES.** Normally, the urine contains insignificant amounts of pyrimidines.

**HIPPURIC ACID.** A small amount of hippuric acid occurs in the normal urine. The range is given as 0.1 to 1.0 gm. per day (average, 0.7 gm.).<sup>35</sup> It is derived from benzoic acid or any substance which by oxidation can give rise to benzoic acid.

Values for the hippuric acid synthesis test are given on page 340.

**IMIDAZOLE DERIVATIVES.** Imidazoles are derived from endogenous sources, but their excretion in the urine is also influenced to a slight extent by protein intake. Kauffman and Engle<sup>31</sup> estimated the daily urinary excretion of imidazoles in normal persons to range from 150 to 600 mg. Koessler and Hanke<sup>36</sup> reported from 118 to 219 mg. in twenty-four hours.

**PHENOLS.** Volterra<sup>71</sup> found the daily excretion of volatile phenols to be 10 to 70 mg.; aromatic hydroxy acids, 49 to 80 mg.; residual phenols, 156 to 203 mg.; and total phenols, 260 to 636 mg.

TABLE 200

## URINARY PHENOLS IN NORMAL SUBJECTS

(Data from Swendseid et al., 1947)<sup>69</sup>

Number of subjects.....	5
Number of determinations.....	13
Ether-soluble phenols:	
NaHCO <sub>3</sub> , fraction A.....	69-132 mg.
NaOH, fraction B.....	48-83 mg.
Ratio of A to B.....	1.2-2.2 mg.
Ether-insoluble phenols, fraction C.....	31-64 mg.
Total phenols, fractions A, B and C.....	167-257 mg.

All values are expressed as milligrams of tyrosine excreted in twenty-four hours. The subjects were on the following diet for two to four days: protein, 85 gm.; fat, 129 gm.; carbohydrate, 226 gm.

**PROTEIN.** The popular tests used in the clinical laboratories usually do not detect the small amount of protein normally present in the urine. However, if measured carefully with refined methods, protein can be demonstrated in practically all urines.

Although the amounts of protein in the urine of normal persons are usually too small to be detected by *routine* tests, a small percentage of normal persons may excrete from time to time amounts large enough to be detected by common clinical laboratory procedures. Such proteinuria is usually referred to as adolescent, orthostatic, benign, postural, physiologic, intermittent or functional. In this type of proteinuria, albumin and globulin are found in the urine in almost equal amounts. The incidence of physiologic proteinuria rises from childhood to puberty, reaching a maximum at about the age of sixteen years (Table 202). The incidence declines rapidly after the age of eighteen and becomes almost negligible after the age of twenty-five.

Proteinuria is more common among girls than among boys.<sup>13</sup>

TABLE 201  
PROTEIN IN NORMAL URINE

<i>Subjects</i>	<i>Protein</i>	<i>Investigator</i>
29.....	23 to 200 mg./L.	Wang and Wu (1937)
Not stated.....	20 to 80 mg./24 hrs.	Kilduffe (1937)
Not stated.....	20 to 80 mg./24 hrs.	Bodansky and Bodansky (1938)
21.....	3 to 60 mg./12 hrs.	Goldring and Wyckoff (1930)
74 Children.....	3 to 47 mg./12 hrs.	Lyttle (1933)

In a study of urines obtained from 22,000 normal adult males there was a decrease in the incidence of proteinuria from age sixteen to over thirty-five years.<sup>77</sup> In a study of 9994 men between the ages of seventeen and fifty years 3 per cent were found to have proteinuria.<sup>51</sup> There appears to be a striking seasonal variation in the occurrence of proteinuria, the incidence being much higher during the summer months (see Table 203 and Fig. 92). Proteinuria was observed in 5 per cent of Harvard freshmen averaging eighteen years of age.<sup>48</sup> In upper classmen with an average age of twenty years the incidence was 3.5 per cent.

TABLE 202  
ALBUMINURIA IN SCHOOL CHILDREN  
(Lauener, 1922)<sup>39</sup>

<i>Age</i>	<i>Number of Children</i>	<i>Percentage Showing Albuminuria</i>	<i>Percentage of Boys with Albuminuria</i>	<i>Percentage of Girls with Albuminuria</i>	<i>Percentage Showing Trace of Albumin</i>
6-7.....	1246	6.7	5	8.5	5.6
10-11.....	1350	27	18.6	35.5	15.6
15-16.....	2481	38	29.5	46	25.5

Excretion of protein in the urine is increased after exercise. Proteinuria was found in approximately one-third of a group of boys seven to thirteen years of age, after long-distance races.<sup>52</sup> No proteinuria was found after short-distance

es. From 0.5 to 6 gm. of protein per 100 ml. were found in twelve of fifteen football players during football season.<sup>50</sup> After the season the urines of all but one player became free of protein.

**SUGAR.** A number of reducing substances are present in the urine of normal persons. These are usually in quantities too small to be detected by routine laboratory procedures. The term "melituria" signifies the presence of any sugar in the urine, glucose being most frequently found. Other components that reduce copper are usually referred to as "saccharoids," and include glucuronides, uric acid, phenol, creatinine and unknown carbohydrates.<sup>5</sup>

TABLE 203

## INCIDENCE OF ALBUMINURIA IN THREE AGE GROUPS

(Murphy, 1944)<sup>51</sup>

Age Groups	Number of Subjects	Number of Orthostatic Albuminurias
17.....	4517	232
18-38.....	4248	23
39-51.....	1229	0

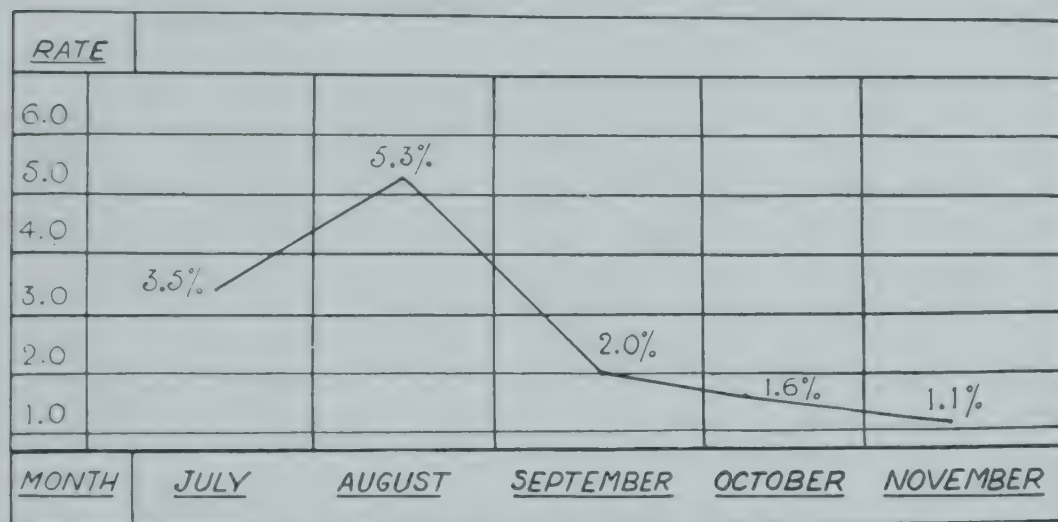


Fig. 92. Seasonal incidence of orthostatic albuminuria per 100 applicants. (Murphy, W. A.: U. S. Nav. M. Bull., vol. 43.)

The normal amount of the total reducing substances excreted in the urine in twenty-four hours is between 0.5 and 1.5 gm.

Melituria is occasionally observed in normal persons. Blotner and Hyde,<sup>7</sup> in a study of 45,650 men, found transient melituria in 126 and "renal" melituria in thirty-three men.

Marble<sup>46</sup> found fifteen cases of renal glycosuria in a study of 9000 cases of glycosuria. Wolman<sup>77</sup> found 0.42 per cent melituries among 77,293 trainees, of whom only 0.03 per cent were found to have diabetes mellitus (Table 204).

**CITRIC ACID.** Citric acid seems to be a constant constituent of urine.<sup>66</sup> It is probably a product of endogenous metabolism, since it continues to appear even during starvation. Its excretion is diminished during menstruation. The amount excreted in the urine in twenty-four hours is between 0.2 and 1.2 gm.

TABLE 204

INCIDENCE AND PERCENTAGE DISTRIBUTION OF MELITURIA ACCORDING TO AGE GROUPS  
(Wolman, 1946)<sup>77</sup>

Age Groups (Yrs.)	Number of Enroll-ees	Transitory	Low Renal Threshold	Renal Glycosuria	Diabetes Mellitus	Undiag-nosed	Total
16-20. . . . .	44,586	88 (0.20%)	9 (0.02%)	4 (0.01%)	9 (0.02%)	15 (0.03%)	125 (0.28%)
21-25. . . . .	13,783	28 (0.20%)	2 (0.02%)		3 (0.02%)	11 (0.08%)	44 (0.32%)
26-30. . . . .	10,911	40 (0.36%)	1 (0.01%)	1 (0.01%)	4 (0.04%)	11 (0.10%)	57 (0.52%)
31-35. . . . .	5,681	45 (0.79%)	4 (0.07%)	2 (0.04%)	1 (0.02%)	8 (0.14%)	60 (1.06%)
36 and over	2,332	24 (1.03%)	3 (0.13%)	...	4 (0.17%)	7 (0.30%)	38 (1.63%)
Totals	77,293	225 (0.29%)	19 (0.02%)	7 (0.01%)	21 (0.03%)	52 (0.07%)	324 (0.42%)

LIPIDS. Slight traces of stearin and palmitin may be present in the urine of normal persons after a high fat diet or after the ingestion of cod liver or other oils.<sup>37</sup>

INORGANIC CONSTITUENTS

The most complete study of mineral balance in normal adults is that reported by Clark of five prisoners over a period of seven months. His data have been summarized by Shohl<sup>62</sup> (Table 205). These subjects must have received an inadequate diet, however, since three of the five gained weight, and all retained both anions and cations. Table 205 includes values for the inorganic components of urine.

SODIUM. Burrill and his co-workers<sup>12</sup> found the daily urinary excretion of sodium in six male adults to be between 4.28 and 4.98 gm. per twenty-four hours. The maximal excretion occurred between 9 and 11 A. M.

POTASSIUM. Freeman and Burrill<sup>23</sup> found the average urinary excretion of potassium in two normal subjects on a constant potassium intake for a period of eleven days to be 2.84 and 3.02 gm. Burrill and his co-workers<sup>12</sup> found the daily urinary excretion of potassium in six men to range from 2.53 to 3.04 gm.

CALCIUM. *The daily urinary excretion of calcium on a normal dietary regimen is from 0.1 to 0.3 gm.* This amount represents 10 to 40 per cent of the total excretion of calcium in normal persons.

Calcium may be regarded as a threshold substance. If its concentration in serum falls below 8 mg. per 100 ml., almost none will be excreted in the urine. If the serum concentration is between 9.5 and 10.5 mg. per 100 ml., and the subject ingests a normal amount of calcium, between 150 and 200 mg. will be excreted daily in the urine. When the concentration of serum calcium increases above 11 mg. per 100 ml., the amount of calcium in the urine is almost always increased.

MAGNESIUM. *The daily output of magnesium in the urine usually amounts to 100 to 300 mg.* The amount depends upon the diet and is approximately 35 per cent of the total excretion of magnesium.

TABLE 205  
MINERAL BALANCE OF NORMAL MEN\*  
(After Shohl, 1939)<sup>62</sup>

Intake.....	Na	3.94 gm.	171 mEq.	Cl	5.17 gm.	146 mEq.†
	K	2.47 gm.	63 mEq.	P	1.48 gm.	86 mEq.†
	Ca	0.88 gm.	44 mEq.	S	0.93 gm.	58 mEq.†
	Mg	0.26 gm.	22 mEq.			
	Total.....		300 mEq.	Total.....		290 mEq.†
Output in urine.....	Na	2.30 gm.	100 mEq.	Cl	3.90 gm.	110 mEq.†
	K	1.80 gm.	46 mEq.	P	0.70 gm.	41 mEq.†
	Ca	0.09 gm.	5 mEq.	Sulfate S	0.53 gm.	33 mEq.
	Mg	0.09 gm.	8 mEq.	Total S	0.61 gm.	38 mEq.†
	Total.....		159 mEq.	Total.....		189 mEq.†
Excretion.....	Na	0.12 gm.	5 mEq.	Cl	0.09 gm.	3 mEq.
	K	0.47 gm.	12 mEq.	P	0.51 gm.	30 mEq.
	Ca	0.64 gm.	32 mEq.	S	0.13 gm.	8 mEq.
	Mg	0.20 gm.	17 mEq.			
	Total.....		66 mEq.	Total.....		41 mEq.†
Total.....	Na	2.42 gm.	105 mEq.	Cl	3.99 gm.	113 mEq.
	K	2.27 gm.	58 mEq.	P	1.21 gm.	71 mEq.†
	Ca	0.73 gm.	37 mEq.	S	0.74 gm.	46 mEq.†
	Mg	0.29 gm.	25 mEq.			
	Total.....		225 mEq.	Total.....		230 mEq.†
Calculated retention.....	Na	1.52 gm.	66 mEq.	Cl	1.18 gm.	33 mEq.
	K	0.20 gm.	5 mEq.	P	0.27 gm.	15 mEq.†
	Ca	0.15 gm.	7 mEq.	S	0.19 gm.	12 mEq.†
	Mg	-0.03 gm.	-3 mEq.			
	Total.....		75 mEq.	Total.....		60 mEq.†
	Cationogen excess		15 mEq.			

\* Calculated from the data of Clark on the intake and output of 5 normal men for a total of 112 weekly periods. No volumes of urine are given.

† The phosphorus is calculated as 1.8 eq. M, the sulfur as 2.0. These are mere stoichiometric conventions. In the urine the equivalent value of phosphorus is about 12; in the feces, 9. In retention it is 3.0 in bone and undetermined in tissue. The value of sulfur in retention approaches zero when sulfur is stored as protein.

TABLE 206

NORMAL URINARY EXCRETION OF MAGNESIUM		
Number of Subjects	Magnesium (Gm./24 Hours)	Investigator
—	0.033–0.307 (average, 0.103)	Walker and Walker (1936)
8	0.084–0.132	Weber (1937)
57	0.172–0.285 (average, 0.106)	Bernstein and Simkins (1940)

IRON. The small amount of iron excreted in normal urine probably occurs in both organic and inorganic combination. Normal values for *total iron* in urine are given in Table 207.

TABLE 207

NORMAL URINARY EXCRETION OF IRON		
Number of Subjects	Iron (Mg./24 Hours)	Investigator
3	0.20	Farrar and Goldhamer (1935)
—	0.20	Sherman (1907)
5	0.06–0.10	Marlow and Taylor (1934)
1	0.045	Little et al. (1935)

LEAD. The amount of lead excreted in the urine ranges from 0.001 to 0.2 mg. per liter (0.004 to 0.15 mg. per twenty-four hours). Mean values for lead in the urine, feces and blood of normal persons engaged in various occupations are given in Table 207a.<sup>14a</sup>

TABLE 207A

MEAN VALUES FOR LEAD IN URINE, BLOOD AND FECES OF GROUPS OF PERSONS UNDER VARYING CONDITIONS OF LEAD EXPOSURE

Occupation	Mean Values					
	Urine		Feces		Blood	
	Number of Persons or Samples	Mg. Pb/L	Number of Persons or Samples	Mg. Pb/24 hr.	Number of Persons or Samples	Mg. Pb/100 g.
No occupational lead exposure	1,052	0.027	859	0.280	188	0.030
Applying insulation	23	0.037	..	..	27	0.037
Garage mechanics	654	0.050	463	0.486	145	0.039
Paint manufacture	20	0.067	20	0.505	20	0.048
Soldering	74	0.074	..	..	15	0.050
Gasoline pump repair	17	0.074	..	..	17	0.041
Manufacture of insecticides	27	0.079	26	0.546	..	..
Manufacture of tetraethyl lead	762	0.093	750	0.458	136	0.045
Manufacture of lead shot	38	0.124	38	1.421	13	0.062
Manufacture of pigments	12	0.124	6	0.500	7	0.086
Brass foundrymen	60	0.161	55	0.592	..	..
Manufacture of storage batteries	69	0.182	71	2.530	..	..
Manufacture of white lead—moderate exposure	86	0.241	85	3.760	21	0.086
Manufacture of white lead—severe exposure	10	0.336	10	7.600	..	..

**NICKEL.** The nickel concentration in the urine of eight normal persons, according to Stanley,<sup>66a</sup> averaged 0.1 mg. per liter, with a maximum of 0.3. These measurements were made by means of a polarograph.

**TRACE METALS.** Using spectrographic methods, Kehoe and his associates<sup>67a</sup> report mean concentrations of trace metals in mg. per liter of normal urine as follows: *manganese, below 0.01; aluminum, 0.078; copper, 0.034; lead, 0.027; tin, 11; and silver, 0.00.*

**CHLORIDE.** The excretion of chloride in urine is greatly dependent upon the type of diet, intake of sodium chloride, body activity, sweating and other factors. Conditions favoring excessive sweating induce a decreased excretion in the urine. *In children the daily urinary excretion of chloride is from 3 to 10 gm. (expressed as sodium chloride); in adults it is from 8 to 15 gm.*

TABLE 208

EXCRETION OF NICOTINIC ACID AND ITS DERIVATIVES: ESTIMATED DAILY NICOTINIC ACID PLUS AMIDE INTAKE

(Johnson, Hamilton and Mitchell, 1945)<sup>32</sup>

Urine Volume per Day (Cc.)	Free Nicotinic Acid (Mg.)	Nicotinamide (Mg.)	N <sup>1</sup> -Methyl Nicotin- amide (Mg.)	Total (Mg.)	Estimated Intake* (Mg.)
50 .....	0.17	0.70	10.8	11.67	19.0
16 .....	0.40	1.28	42.3	44.0	30.0
90 .....	0.21	0.80	8.5	9.5	15.3
30 .....	0.17	0.87	13.1	14.1	20.1
Average .....	0.24	0.91	18.7	19.8	21.1
Per cent of total .....	1.2	4.6	94.4	100.0	

\* These estimates are made from the lower range of values obtained by the microbiological assay method of Snell and Wright.

**SULFUR.** *The total daily excretion of sulfur in the urine is between 2 and 3.4 gm. (as sulfur trioxide).<sup>28</sup> The quantity varies with the protein intake of the diet. The total sulfur<sup>28</sup> includes:*

1. Inorganic sulfates (of sodium, potassium, calcium and ammonia), 1.7 to 2.7 gm. (as sulfur trioxide).
2. Ethereal sulfates (potassium and sodium salts of indoxyl sulfuric acid), 0.15 to 0.3 gm. (as sulfur trioxide).
3. Neutral sulfur (found in amino acids, urochrome, thiosulfates, thiocyanates, taurocholic acid), 0.2 to 0.4 gm. (as sulfur trioxide).

**PHOSPHORUS.** *The daily urinary excretion of phosphorus is about 1.1 gm., depending upon the diet. Most of the phosphorus is in the inorganic state (i. e.,  $\text{H}_2\text{PO}_4^-$  and  $\text{HPO}_4^{2-}$ , depending upon the reaction), although a small amount, 1 to 4 per cent, exists in organic combination.*

**KETONE BODIES.** *In the urine of adults on a mixed diet, the output of ketone*

bodies is about 20 mg. daily.<sup>5 16 31</sup> Amounts in excess of 20 mg. are regarded as probably pathologic.

**PORPHYRIN.** Coproporphyrin 1 is excreted in small amounts in the urine of normal persons. Table 77 on page 133 gives the amount excreted in twenty-four hours as reported by various investigators. A detailed discussion of porphyrias is given in Chapter 16.

**UROBILINOGEN.** This constituent occurs in small quantities in the normal urine. On exposure to light it is oxidized to urobilin. *The daily excretion of uro-*

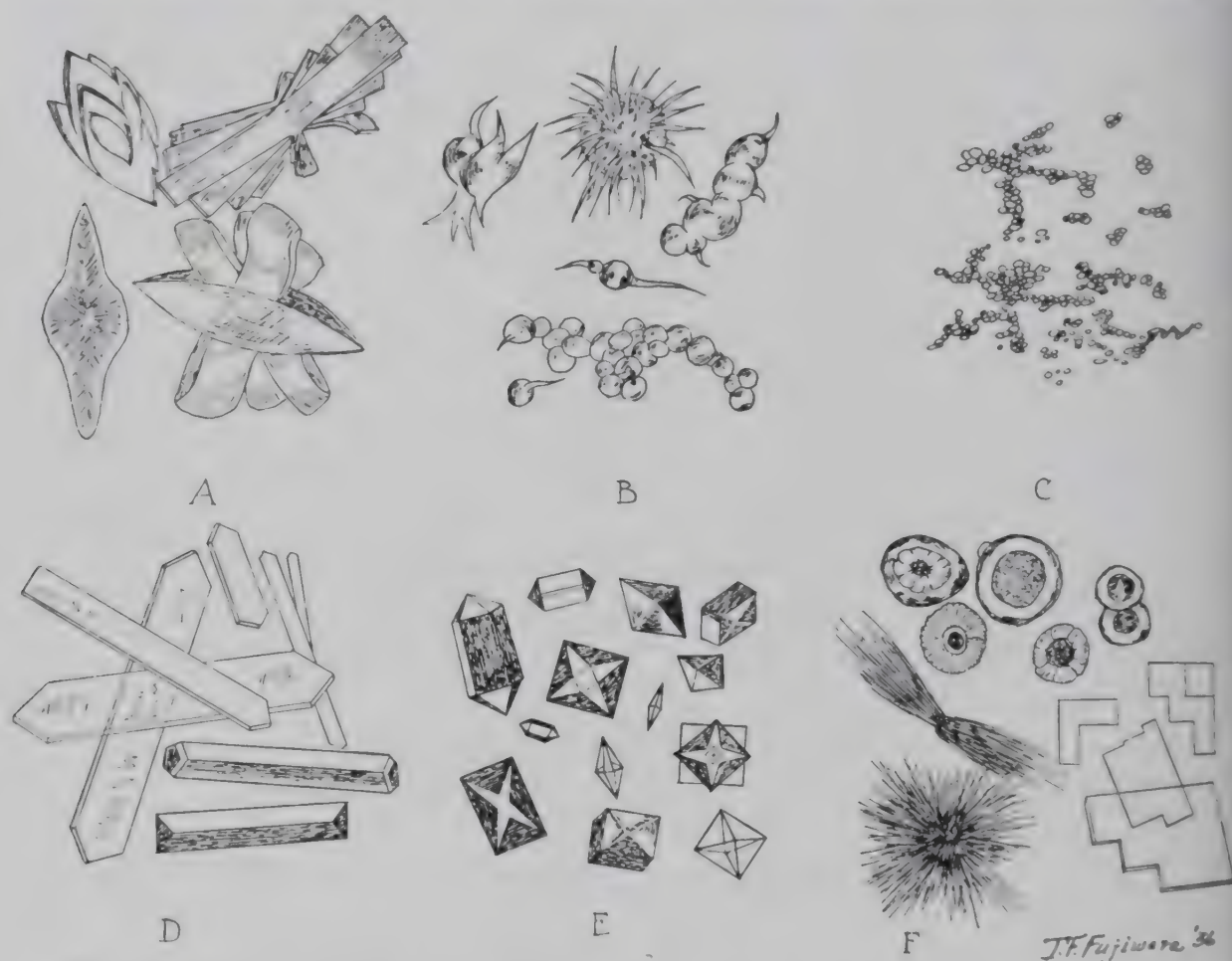


Fig. 93. Common sediments of acid urine, showing crystals of: A, uric acid; B, ammonium urate; C, amorphous urates; D, hippuric acid; E, calcium oxalate; F, tyrosine needles, leucine spheroids and cholesterol plates. (Adapted from Atlas of Urinary Sediments by Hermann Rieder. Parker, F. P.: Textbook of Clinical Pathology, Williams & Wilkins Company.)

bilinogen is regarded as 0 to 4 mg., but it is usually between 0.5 and 2.0 mg.<sup>78</sup> The amount of urobilinogen detected in the urine depends upon the method used.<sup>67</sup> By the Watson method the quantity excreted in the urine of normal persons may vary from 0.2 to 3 mg., with about 80 per cent between 0.4 and 1.4 mg. Measurements made according to the Sparkman<sup>66</sup> method yield quantities between 3 and 25 mg. during twenty-four hours, with 82 per cent of the subjects excreting between 5 and 13 mg. By the Wallace and Diamond<sup>68</sup> method any positive reaction (i. e., a red color from urobilinogen and Ehrlich's aldehyde reagent) above a 1:20 dilution is considered abnormally high. A failure to obtain a positive reaction with undiluted urine is abnormally low.

## URINARY VITAMINS

Various vitamins are present in the urine of normal persons [see Table 208]. amounts found frequently depend on the quantity already present in the tissues, vitamins in the diet, and environmental conditions.

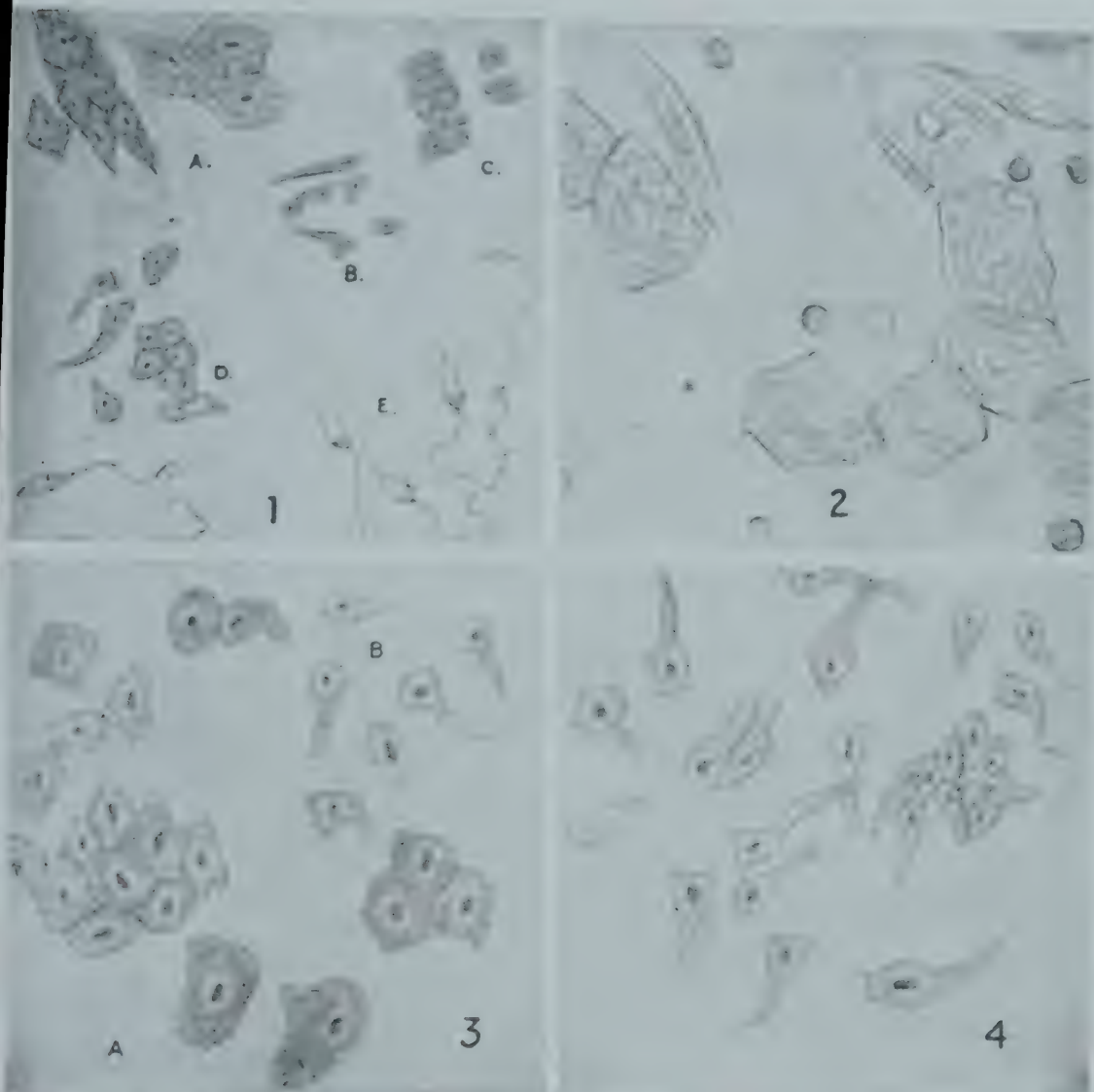


Fig. 94. Urinary epithelium and spermatozoa. 1, A, Vaginal epithelium; B, ureteral epithelium; C, renal epithelium; D, epithelium from pelvis of kidney; E, spermatozoa—all after detrit. 2, Squamous epithelium and pus cells—after Todd and Sanford. 3, Epithelium from urethra; B, and bladder (A)—after Todd and Sanford. 4, Epithelium from pelvis of kidney—after Todd and Sanford. (Kolmer, J. A., and Boerner, F.: *Approved Laboratory Technic*, Appleton-Century Company, Inc.)

**ASCORBIC ACID.** There is great variation in the excretion of ascorbic acid in the urine in the same person from day to day, depending upon the ascorbic acid intake. *The amount excreted in twenty-four hours is usually 15 to 50 mg.*

**FOLIC ACID (Folacin).** *From 0.0038 to 0.0238 mg. of folic acid (average, 0.0108 mg.) is excreted daily in the urine.<sup>31</sup> About five to six times as much folic acid is excreted through the sweat as through the urine.<sup>32</sup>*

**NIACIN (NICOTINIC ACID).** *The daily excretion of niacin and its derivatives*

ranges from 9.5 to 44.0 mg.<sup>28</sup> The amounts varied directly with the intake. About 95 per cent of the total (Table 208) is N<sup>1</sup>-methyl-nicotinamide.

Goldsmith<sup>29</sup> reports a range of nicotinic acid excretion in ten normal subjects between 9.5 and 22.1 mg. in twenty-four hours (average, 15.6 mg.).

Melnick, Robinson and Field,<sup>30</sup> in a study of eleven well-nourished persons, found the amounts of urinary nicotinic acid excretion in twenty-four hours to



Fig. 95. Urinary leukocytes, erythrocytes, molds and artefacts. 1, Leukocytes (after Todd and Sanford). 2, Erythrocytes (after Todd and Sanford). 3, Molds (after Riedert). 4, Artefacts (after Riedert). (Kolmer, J. A., and Boerner, F.: *Approved Laboratory Technic*, D. Appleton-Century Company, Inc.)

vary between 1.7 and 29.3 mg. The average excretion of nicotinic acid as trigonelline was approximately 50 mg. per twenty-four hours.

**FAT-SOLUBLE VITAMINS (A, D, E AND K).** These vitamins occur in small amounts or not at all in the urine of normal persons.

### URINARY HORMONES\*

\* The various hormones found in the urine are given in Section XV. For Gonadotrophic Hormones and Pregnancy Tests, see Chapter 60; for normal Urinary Estrogens, see Chapter 48; for Progesterone, see Chapter 59; for Androgens and 17-Ketosteroids, see Chapter 57.

## FORMED ELEMENTS IN URINE

On careful microscopic examination of normal urine, casts, erythrocytes, leukocytes, crystals and other organized and unorganized substances can be

TABLE 209

CELLULAR ELEMENTS IN URINE FOR 12-HOUR PERIOD (NORMAL ADDIS COUNTS)

<i>Subjects</i>		<i>Casts</i>	<i>Erythrocytes</i>	<i>Epithelial Cells and Leukocytes</i>	<i>Investigator</i>
Men (medical students) . . . . .	Range Average	0-4270 1040	0-425,000 65,750	32,400-1,000,000 322,550	Addis(1925)
Adults . . . . .	Range Average	0-9200 647	0-1,530,000 163,000	24,000-3,400,000 647,500	Goldring (1931)
Children of both sexes, aged to 12 years . . . . .	Range Average	0-12,916 1085	0-129,000 15,181	900-2,822,000 322,184	Lyttle (1933)
Children of both sexes, aged to 14 years . . . . .	Range Average	0-20,000 1526	0-1,000,000 171,969	300,000-20,000,000 3,500,000	Soto Pradera and Lopez de la Junquera (1938)
Boys, aged 3½ to 9½ years . . . . .	Range Average	0-37,800 16,600	60,000-157,000 86,800	366,000-840,000 631,000	Rew and Butler (1932)
Girls, aged 5½ to 10½ years . . . . .	Range Average	0-34,000 14,800	21,000-374,000 180,000	495,000-4,106,000 2,160,000	

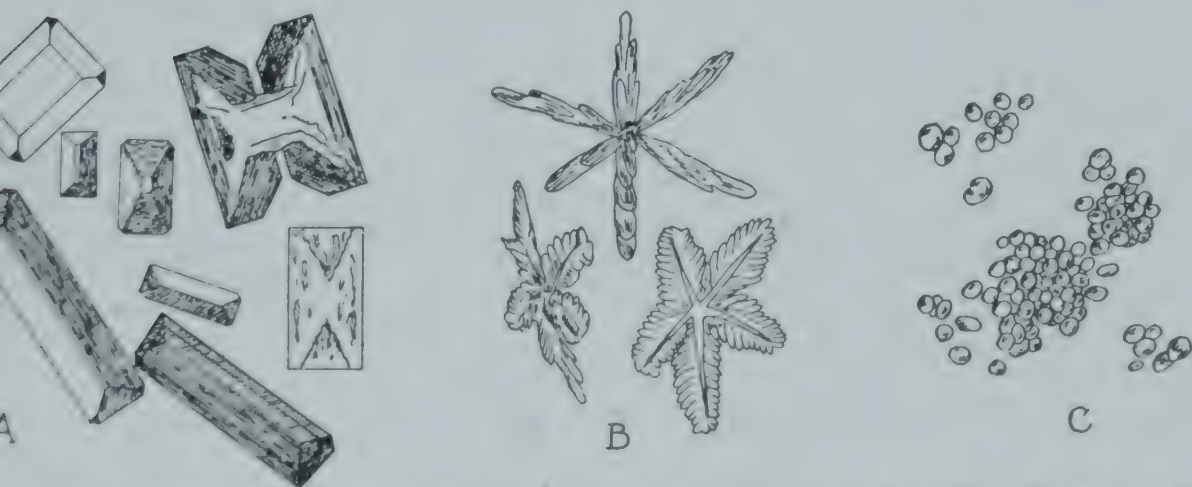


Fig. 96. Common sediments of alkaline urine: A, ammonium and magnesium triple phosphates freshly formed; B, triple phosphates going into solution; C, amorphous phosphates. (Adapted from Atlas of Urinary Sediments by Hermann Rieder.) (Parker, F. P.: Textbook of Clinical Pathology, Williams & Wilkins Company.)

detected frequently. The technic, collection and preservation of the urine are of great importance in preventing the destruction and disappearance of the elements before the urine is examined.

**CELLULAR ELEMENTS AND CASTS.** The quantitative enumeration of cells and casts by the method proposed by Addis<sup>1</sup> gives the approximate number of cells passed in a twelve-hour specimen. Wide variations occur in normal subjects, and no close division can be drawn between normal and abnormal (Table 209). The casts found in normal urine are mostly hyaline, but also include a few granular types.

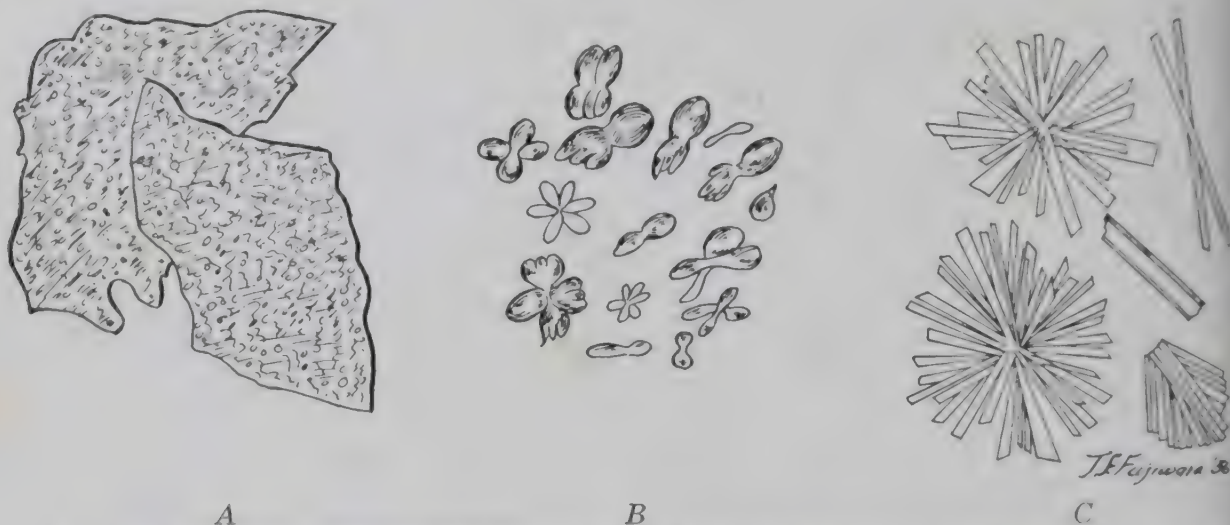


Fig. 97. Common sediments of alkaline urine: A, neutral calcium phosphates; B, calcium carbonate; C, calcium sulfate. (Adapted from Atlas of Urinary Sediments by Hermann Rieder. (Parker, F. P.: Textbook of Clinical Pathology, Williams & Wilkins Company.)

**CRYSTALS.** Crystals may occur as definite structures or as amorphous deposits. The types of crystals in normal urine depend upon the metabolic activities of the body, the diet and length of time after voiding. Freshly voided normal urine is usually free of crystals. The substances which precipitate as crystals or amorphous substances are usually voided in solution, and precipitate owing to alteration upon standing.

**MUCUS.** Traces of mucus may be found in normal urine and occur as threadlike strands.

<i>Sediments</i>	<i>Urine Reaction</i>	<i>Forms</i>	<i>Usual Size</i>	<i>Chemical Behavior</i>
Calcium oxalate	Neutral, alkaline or acid, but usually acid	Octahedral or envelope form with highly refractive center Dumb-bell type	Octahedra small as a rule, about the size of R.B.C.; seen as points of light under low power	Insoluble in acetic acid; soluble in strong HCl; insoluble in NaOH
Uric acid	Acid	Yellow or brown-red rhombic prisms, wedges, rosettes, irregular plates, somewhat oval forms with pointed ends. The rhombic plates may be colorless, although uric acid crystals are recognized largely by color	Large "brick dust" can be detected macroscopically. Colorless forms tend to be smaller than pigmented	Soluble in NaOH, in ammonia with subsequent formation of ammonium urate crystals; insoluble in acetic acid and HCl
Sodium urates*	Acid	Amorphous; light or dark brown granules in mosslike arrangement Crystalline; colorless needles or fan-shaped clusters	Recognizable under low power	Dissolve on heating; soluble in NaOH, in HCl or acetic acid with formation of uric acid crystals in 10 to 20 minutes
Ammonium urates	Alkaline (free ammonia)	Opaque, yellow crystals, smooth and spherical or covered with spicules, "thorn-apples"	Easily recognized with low-power magnification	Soluble in acetic acid like sodium urates
Ammonium magnesium phosphate (triple phosphate)	Alkaline; also in slightly acid urine if there is an abundance of ammonium salts	"Coffin lids" Square prisms which can be distinguished from calcium oxalate by the size and highly refractive center of the latter as well as by chemical means Irregular prisms. Disintegrating prisms. Feathery, leaflike forms	Very large	Soluble in acetic acid
Calcium carbonate	Usually alkaline	Dumb-bells, single or clustered	Smaller than calcium oxalate	Soluble in acetic acid with evolution of CO <sub>2</sub>
Calcium phosphate† stellar phosphate	Alkaline	Amorphous; colorless globules or granules, single or clustered Crystalline; wedge-shaped, single or rosettes	Recognizable under low power	Soluble in acetic acid

\* Calcium, magnesium and potassium urates are amorphous. They are found in concentrated urine of strong acidity.

† Phosphate crystals resembling thin broken sheets of ice are frequent in urine of mild reaction.

TABLE 211  
CONSTITUENTS OF URINE (NORMAL RANGES FOR ADULTS)\*

	<i>Amount per 24 Hours</i>
Volume.....	600–2000 ml.
Total solids.....	55–70 gm.
Specific gravity.....	1.105–1.025
pH.....	4.6–8.0
Albumin.....	See <i>Protein</i>
Allantoin.....	10–25 mg.
Aluminum.....	0.078 mg./L. <sup>34a</sup>
Amino acids:	
Free.....	0.5 gm.
Total.....	1.1 gm.
Nitrogen.....	( 0.2–0.4 gm. <sup>28</sup> 0.2 gm. <sup>29</sup> )
(See also Table 199 for individual amino acids)	
Ammonia.....	{ 0.5–1.0 gm. 0.3–0.7 gm. <sup>49</sup>
Amylase.....	264–953 mg. of glucose <sup>17</sup>
Arginine.....	0.05–0.15 gm. <sup>3</sup>
Calcium.....	0.1–0.3 gm. <sup>29</sup>
As CaO.....	0.1–0.4 gm. <sup>49</sup>
Chlorides.....	{ 10–15 gm. as NaCl <sup>28</sup> 35 8–10 gm. as NaCl <sup>49</sup>
Cholesterol.....	0–0.5 mg. <sup>49</sup>
Citric Acid.....	0.2–1.2 gm.
Copper.....	0.034 mg./L. <sup>34a</sup>
Creatine.....	0–60 mg. <sup>10</sup>
Creatinine.....	1.2–1.7 gm.
Cystine:	
Free.....	{ 0.088–0.025 gm. <sup>30</sup> 0.04–0.08 gm. <sup>30</sup>
Total.....	0.10–0.20 gm. <sup>56</sup>
Fluorides.....	Trace
Hippuric acid.....	0.10–1.0 gm.
Hormones.....	See <i>Section XV</i>
Imidazole derivatives.....	{ 0.15–0.60 gm. 0.118–0.219 gm.
Indican.....	{ 4–20 mg. <sup>35</sup> 5–10 mg. <sup>10</sup>
Iodine.....	{ 18–483 micrograms <sup>11</sup> 20–70 micrograms <sup>10</sup>
Iron.....	0.06–0.10 gm.
As Fe <sub>2</sub> O <sub>3</sub> .....	0.3 mg. <sup>49</sup>
Ketone bodies.....	0.04–0.05 gm. <sup>49</sup>
17-Ketosteroids:	
Men.....	15 mg. <sup>29</sup>
Women.....	10 mg. <sup>37</sup>
Lactic acid.....	0.05–0.20 gm.
Lead.....	0.004 to 0.15 mg.
Magnesium.....	{ 32.5–307 mg. 83.9–132.1 mg.
As MgO.....	100–300 mg. <sup>49</sup>
Manganese.....	0.01 mg./L. <sup>34a</sup>
Nickel.....	0.15 mg. <sup>66a</sup>
Nitrates.....	0.5 gm. <sup>29</sup>
Nitrogen, total.....	10–15 gm. <sup>49</sup>
Oxalic acid.....	{ 0.001–0.02 gm. <sup>28</sup> 0.01–0.03 gm. <sup>35</sup>

\* For normal values for children, consult the text.

TABLE 211—Continued

	Amount per 24 Hours
Phenols . . . . .	{ 100–300 mg. <sup>10</sup> 167–257 mg.
Phosphate, as P . . . . .	0.8–1.3 gm. <sup>58</sup>
Organic PO <sub>4</sub> . . . . .	1–4 per cent of total <sup>29</sup>
Porphyrin . . . . .	0–30 micrograms <sup>10</sup>
Potassium . . . . .	2.53–3.04 gm.
Protein . . . . .	{ 3–60 mg. 20–80 mg.
Purine bases . . . . .	0.01–0.06 mg. <sup>10</sup>
Reducing substances . . . . .	0.5–1.5 gm. <sup>10</sup>
Silicates . . . . .	Trace
Sodium . . . . .	4.28–4.98 gm.
Solids . . . . .	55–70 gm. <sup>10, 28</sup>
Sulfur:	
Inorganic sulfates (as SO <sub>3</sub> ) . . . . .	1.7–2.7 gm.
Ethereal sulfates (as SO <sub>3</sub> ) . . . . .	0.15–0.3 gm.
Neutral sulfur (as SO <sub>3</sub> ) . . . . .	0.2–0.4 gm.
Total (as SO <sub>3</sub> ) . . . . .	2.0–3.4 gm.
Tin . . . . .	0.011 mg./L.
Urea . . . . .	{ 25–35 gm. 15–35 gm.
Uric acid . . . . .	0.5–1.0 gm.
Urobilin . . . . .	10–130 mg. <sup>10</sup>
Urobilinogen:	
Watson method . . . . .	0.2–3.0 mg.
Sparkman method . . . . .	3.0–25.0 mg.
Wallace and Diamond method . . . . .	Negative in dilutions over 1:20
Vitamins:	
Ascorbic acid . . . . .	15–50 micrograms <sup>68</sup>
Biotin . . . . .	3–3.1 micrograms <sup>64</sup>
Choline . . . . .	5.6–9.0 mg. <sup>14</sup>
Folic acid . . . . .	0.0038–0.238 mg.
Niacin . . . . .	{ 9.5–44.0 mg. 9.5–22.1 mg. 1.7–29.3 mg.
Pantothenic acid . . . . .	1.46–6.79 mg. <sup>54</sup>
Pyridoxine (B <sub>6</sub> ) . . . . .	Less than 1.0 microgram <sup>60</sup>
Riboflavin (B <sub>2</sub> ) . . . . .	{ 819–1250 micrograms <sup>19</sup> 700–1700 micrograms <sup>22</sup> 108–390 micrograms <sup>14</sup>
Thiamine hydrochloride (B <sub>1</sub> ) . . . . .	{ 44–229 micrograms <sup>27</sup> 70–150 micrograms <sup>33</sup>
A, D, E and K . . . . .	Trace or none
Water . . . . .	90–95 per cent

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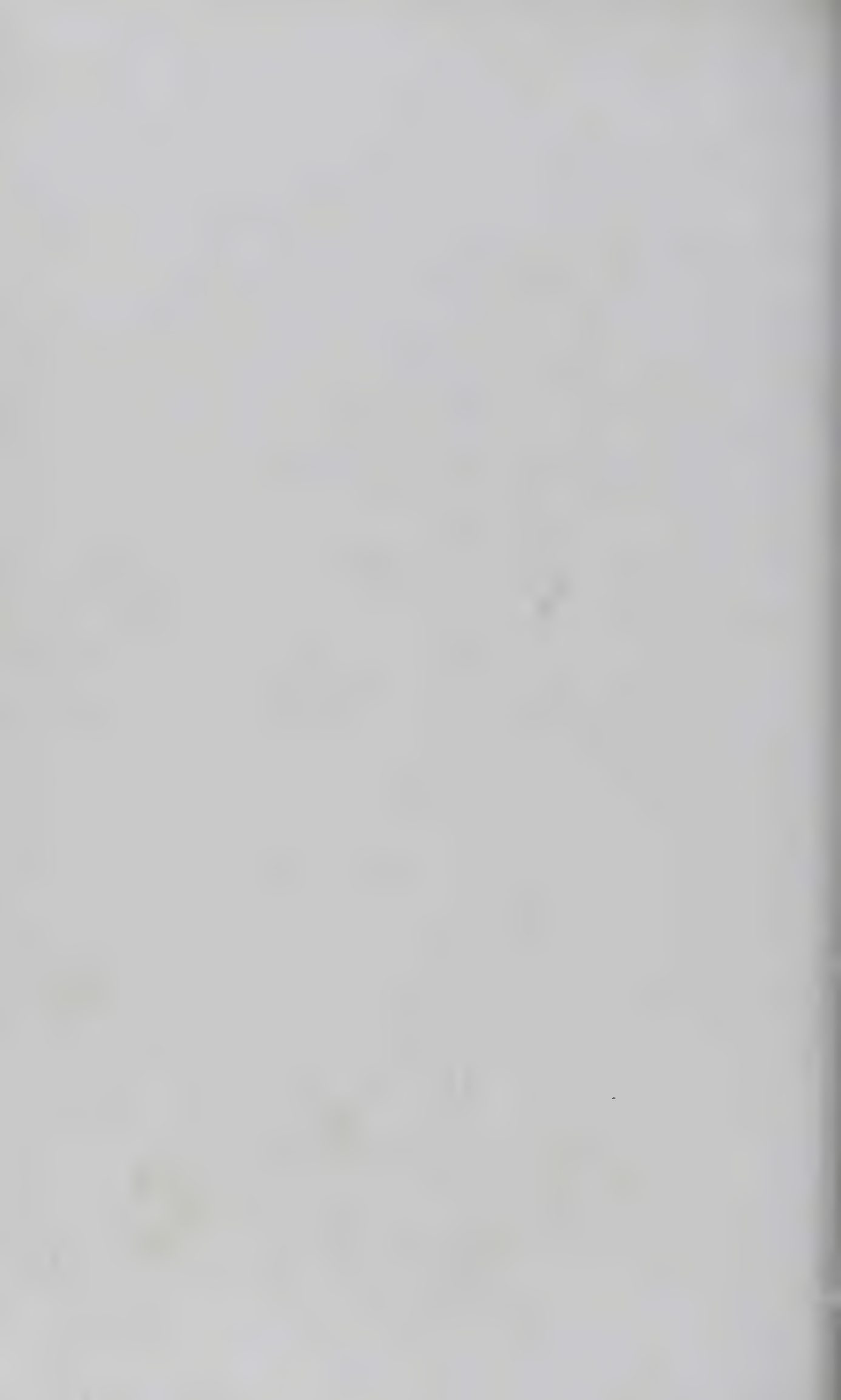
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Section VIII

MALE GENITALIA

(Normal Values in Urology)



# Chapter 42

## EXTERNAL GENITALIA

### THE PENIS

THE PENIS is made up of three erectile bodies (the two corpora cavernosa and the corpus spongiosum), the anterior urethra, and their encompassing fascia and skin. The erectile tissue grossly resembles the structure of a rubber

TABLE 212  
 MEDIAN FOR LENGTH AND CIRCUMFERENCE OF PENIS, AND FOR VOLUME OF TESTIS, BY AGE  
 (Schonfeld and Beebe, 1942)<sup>7</sup>

Age	Number of Subjects	Penis			Volume of Testis (Cc.)
		Length (Cm.)	Circumference		
			Relaxed (Cm.)	Erect* (Cm.)	
0-5 months.....	125	3.75	3.63	4.91	.52
6-11 months.....	51	4.04	3.70	5.01	.72
1-2 years.....	50	4.59	3.89	5.26	.74
3-4 years.....	50	5.04	4.06	5.48	.83
5-6 years.....	50	5.43	4.05	5.47	.80
7-8 years.....	50	5.75	4.10	5.53	.82
9-10 years.....	50	6.00	4.19	5.65	.79
11-12 years.....	50	6.02	4.27	5.76	.75
13-14 years.....	50	6.17	4.46	6.01	.82
15-16 years.....	50	6.21	4.23	5.70	.83
17-18 years.....	50	6.32	4.45	5.99	.94
19-20 years.....	82	6.20	4.57	6.15	.95
21-22 years.....	91	6.56	4.74	6.37	1.48
23-24 years.....	93	7.13	5.05	6.78	2.22
25-26 years.....	104	8.73	5.79	7.76	4.86
27-28 years.....	121	9.77	6.88	9.19	7.72
29-30 years.....	101	11.81	7.62	10.16	11.76
31-32 years.....	76	12.50	7.99	10.65	12.61
33-34 years.....	61	13.26	8.43	11.23	15.12
35-39 years.....	71	13.11	8.61	11.47	16.06
40-45 years.....	54	13.02	8.55	11.39	16.47

\* The circumference of the erect penis has been estimated from the values for the stretched but flaccid penis.

spongy, consisting of sinuses lined by endothelial cells on fibrous trabeculae. The interstices intimately communicate with each other and empty directly into the veins. The glans penis is also made up of erectile corpus spongiosum.

The glans is covered by a delicate semimucous membrane containing many sebaceous glands. The meatus of the urethra is at the distal point of the glans and is 5 to 6 mm. long. The size of the penis varies with age and from one person to another (Table 212).

### THE TESTICLES

The testicles include two essentially different types of organs, the testes and the epididymes.

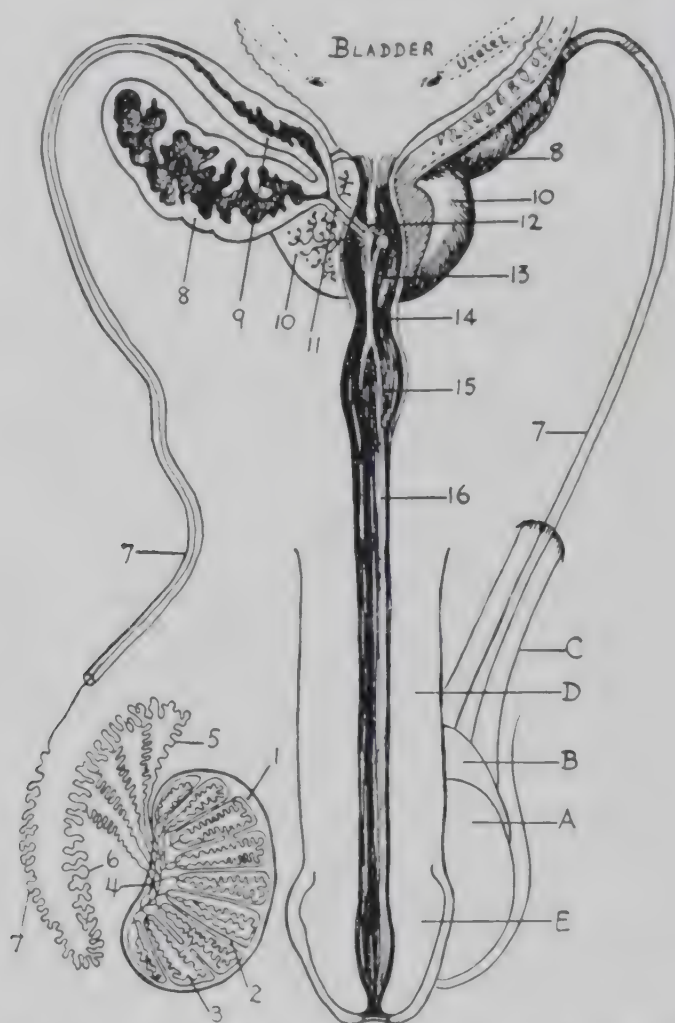


Fig. 98. Sketch of male genital organs. A, Testis; B, head of epididymis; C, spermatic cord; D, penis; E, glans penis; 1, tunica albuginea; 2, septum of testis; 3, seminiferous tubule; 4, mediastinum with rete testis; 5, ductulus efferens; 6, ductus epididymis; 7, ductus deferens; 8, seminal vesicle; 9, ampulla of ductus deferens; 10, prostate gland; 11, ejaculatory duct; 12, colliculus seminalis with opening of utriculus prostaticus; 13, 14, 16, prostatic, membranous and penile portions of urethra; 15, bulb of urethra. (After Dickinson.) (From Bailey's Textbook of Histology, Williams and Wilkins Co.)

The testes are the two sex glands where spermatogenesis takes place and the male sex hormones are elaborated. These glands are two slightly flattened ellipsoidal bodies suspended within the scrotum with their long axes parallel to that of the body. They vary somewhat in size, the average dimensions being 4 to 4.5 cm. in length, 2 cm. in thickness, and 2.5 cm. in breadth. The weight of the adult testicle (with epididymis attached) is 20 to 30 gm. The two testes

h the epididymis attached double their weight in the first two years of life, and after the second year slowly increase in weight as the male approaches adulthood.

The testis itself is surrounded by a stout capsule, the tunica albuginea (fig. 98), a dense, fibro-elastic covering 0.4 to 0.6 mm. in thickness that gives form to the gland and protects the enclosed soft tissues. The space within this capsule is separated by membranous septae that divide the organ into pyramidal lobes, each of which contains from one to three convoluted seminiferous tubules.

### THE SEMINIFEROUS TUBULES

The seminiferous tubules are structural units of the testes and begin as blind canals. Each tubule is approximately 0.15 to 0.25 mm. in diameter and 5 to 70 cm. in length. Since each testis contains 300 to 600 tubules, the combined length of the tubules for both testes measures almost a half a mile. The tubules are very tortuous and pass from the periphery to the posterior aspect of the testicle, where they unite and empty into the rete testis, which join further to form the ductulus efferens (Fig. 98). The epithelial lining of the seminiferous tubules includes two types of cells, the supporting (cells of Sertoli) and the spermatogenic. Within the loose connective tissue between the tubules are interstitial cells (cells of Leydig) which are believed to elaborate the male sex hormone,<sup>2, 3, 6</sup> although the evidence is not entirely conclusive.

### THE SEMINAL DUCTS

The spermatozoa, after being freed in the seminiferous tubules, move toward the rete tubules and from there pass into vasa efferentia, twelve to fifteen ducts which join to form a single tubule, the proximal end of which becomes the globus major of the epididymis. The vasa efferentia are approximately 1 cm. long and contain cilia. As the spermatozoa leave the testicle they enter the seminal duct, which is made up of the epididymis, the vas deferens, the seminal vesicle and the ejaculatory duct.<sup>3, 4</sup> The spermatozoa move through the human seminal duct in nineteen to twenty-three days.<sup>1</sup>

### THE EPIDIDYMIS

The epididymis is a crescentic-shaped compact body made up of a single tubule, much twisted on itself, which is about 20 feet long and 4 mm. wide. The length of the epididymis, according to Oslung,<sup>5</sup> is 26 feet. It is invested in the tunica vaginalis, which is about 2 inches in length. There are no cilia in the lumen of the epididymal tube. The spermatozoa are in an acid environment while in the epididymis and are not actively motile.<sup>3, 4, 6</sup>

### VAS DEFERENS OR DUCTUS DEFERENS

The vas deferens is a single tubule, 15 to 24 inches long, which runs from the tail of the epididymis to the ejaculatory duct. Its course is winding, attended by movements of the testicle and the degree of filling and emptying the bladder. It follows the spermatic cord to the internal inguinal ring, where it leaves the

spermatic vessels, making a sharp bend medially, crosses the external iliac artery, and descends into the pelvis at the base of the bladder, crossing in front of the ureter. At its distal end it widens to form the ampulla of the vas. The vas exhibits peristaltic action and has cilia in its lumen.<sup>3, 4</sup>

The ampulla is a dilated spindle-like enlargement about  $\frac{3}{4}$  inch long, and when distended its volume is about 2 ml.<sup>5</sup>

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## Chapter 43

### THE SEMINAL VESICLES

THE SEMINAL vesicles are two ovoid, sacculated pouches about 2 inches long which lie between the base of the bladder and the rectum, above and behind the prostate. They consist of a coiled tube 15 cm. long, with numerous diverticuli.<sup>6</sup> The normal vesiculogram shows ten to twelve close-lying convolutions of uniform breadth and density. The gland has a pyriform shape, the proximal part being the widest.<sup>7</sup>

The function of the seminal vesicles is primarily the secretion of substances necessary for the seminal fluid. This secretory activity begins at puberty. They, together with the prostate, are the most important of the accessory sex glands.

**CAPACITY.** The capacity of the seminal vesicles is 2 to 7 ml. (average, 5 ml.).<sup>5</sup>

**SECRETION.** The seminal vesicle secretion is yellow and viscid and has a pea-soup-like consistency.<sup>1</sup>

**CHEMICAL CONSTITUENTS.** The most important chemical constituents of the seminal vesicle secretion are phosphates, reducing substances, nonprotein nitrogen, and chlorides; all these are present in the same concentrations found in seminal fluid. There is strong evidence that the seminal vesicle epithelium is the source of these substances as they appear in the semen.<sup>2</sup>

The reducing substance in the seminal secretion which has its source in the seminal vesicle was formerly assumed to be glucose.<sup>2, 3</sup> In four cases Huggins and his co-workers found 275 to 417 mg. per 100 ml. It has recently been shown that this reducing carbohydrate is not glucose, but is d-fructose.<sup>4</sup> Mann found little, if any, glucose in the seminal plasma. The source of the fructose is the seminal vesicles, and its function is to provide the sperm with readily glycolyzable material.

### EJACULATORY DUCTS

The ejaculatory ducts are continuations of the outlets of the seminal vesicles and form the means of passage of the vesical contents to the posterior urethra. They run forward and downward between the middle and posterior lobes of the prostate and terminate in the posterior urethra as slitlike openings on each side or on the lips of the utricle. The length of the right ejaculatory duct in sixty-six normal specimens ranged from 0.9 to 2.1 cm. (average, 1.46 cm.). The left duct ranged from 1 to 2.1 cm. (average, 1.47 cm.) in length.<sup>6</sup>

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## Chapter 44

### PROSTATE GLAND

THE PROSTATE is a firm, partly glandular and partly muscular body located immediately below the internal urethral sphincter or the vesical orifice, and is surrounded by the triangular ligament and surrounding the prostatic urethra. It is an accessory organ, shaped somewhat like a horse-chestnut with its apex or distal end pointed downward and its base toward the rectum. Histologically, it is a compound tubuloalveolar structure divided into follicles surrounded by smooth muscle fibers. These fibers run in both longitudinal and circular directions and blend intimately with the musculature of the bladder. The lumen of the gland is lined by secretory cells which contain fat droplets, fatty acids, cholesterol, lecithin and myelin. The organ consists of five lobes, two lateral, a posterior, a median and an anterior lobe.<sup>2, 5</sup>

**SIZE.** Lowsley<sup>10</sup> and Moore<sup>13</sup> independently studied the size of the normal prostate. Lowsley found that the prostate of a child in the first decade was slightly larger than at birth, the average at five years being 1.2 cm. long, 0.8 cm. wide, and 0.9 cm. thick. He found a great increase in size after the twelfth year, the enlargement involving all lobes except the anterior lobe. The average dimensions of ten specimens from youths between the ages of fifteen and twenty years were 3 cm. long, 3.8 cm. wide, and 2.1 cm. thick. Lowsley found that the prostate reaches adult size during the third decade and changes only slightly after that age, the average adult size being 3.3 cm. in length, 4.1 cm. in width and 2.4 cm. in thickness. There is some slight increase during the fifth and sixth decades, with some decrease during the period of sterility.

TABLE 213  
SIZE OF PROSTATE  
(Moore, 1936)<sup>13</sup>

Decade	Observations*	Volume (Cm.)	Cephalocaudal Axis (Cm.)	Lateral Axis (Cm.)	Anteroposterior Axis (Cm.)
3rd	22	10.22 ± 1.09	2.75 ± 0.116	3.60 ± 0.119	1.89 ± 0.09
4th	24	11.72 ± 0.799	2.92 ± 0.111	3.71 ± 0.088	1.95 ± 0.11
5th	18	10.88 ± 0.788	2.87 ± 0.085	3.67 ± 0.083	1.96 ± 0.11
6th	31	12.03 ± 0.804	2.91 ± 0.071	3.75 ± 0.086	2.06 ± 0.09
7th	22	12.06 ± 1.01	2.85 ± 0.114	3.68 ± 0.081	2.01 ± 0.09
8th	9	11.94 ± 1.11	2.87 ± 0.080	3.78 ± 0.125	2.05 ± 0.11
9th	3	13.70 ± 1.39	3.00 ± 0.205	4.37 ± 0.173	2.17 ± 0.12

\* The 120 individual observations were studied by the statistical method of analysis of variance for significant differences between the decades.

**WEIGHT.** The weight of the prostate varies from 16 to 24 gm. A study of normal males showed the average weight of the encapsulated gland to be 5 gm.<sup>1</sup> In another study of the normal and hypertrophied prostate Teem<sup>2</sup> found that the weight of the gland of the normal adult averaged 20.9 gm.

### PROSTATIC SECRETION

The prostate excretes a fluid which can be expressed from the gland by static massage and which forms part of the seminal fluid at the time of ejaculation. The normal prostatic secretion is thin, white and slightly opaque opalescent. When examined in the fresh state under the microscope, the morphologic constituents shown in Figure 99 may be seen:<sup>3,4</sup>



Fig. 99. The microscopic appearance of normal prostatic secretion. The laminated bodies corpora amylacea. The other large cells are prostatic granule cells. The next smaller are morphonuclear leukocytes in normal numbers. The remainder of the field is studded with lecithin bodies which are characteristic of this secretion. (Pelouze: Office Urology.)

1. Lecithin granules or lecithin bodies are fine, round, refractile globules ranging in size from a minute point to slightly less than a red blood cell. They are thought to be made up of lecithin-like material; according to Scott,<sup>5</sup> however, they are not lecithin, but are fat globules, as first described by Fünfänger.<sup>6</sup>
2. Prostatic granular cells are large, round or irregularly-shaped cells seemingly made up entirely of granules.
3. Corpora amylacea are smooth, spheric, light-yellowish-brown bodies measuring about 250 microns in diameter. On microscopic section they appear as round, colorless disks which stain lightly acidophilic without the eosin stain. They are formed, desquamated epithelial cells mixed with prostatic secretion and are composed largely of protein and nucleic acid.<sup>7,8,9</sup>

- 4. Epithelial cells.
- 5. Leukocytes are few in number (up to 5 per high power field).
- 6. Amorphous material.

AMOUNT. At frequent intervals, if not constantly, the prostate secretes small amounts of fluid. Huggins calls this the "resting fluid." Basing their estimation on the amount of acid phosphatase excreted in the urine (an average of 613 King and Armstrong units per day), Scott and Huggins<sup>18</sup> estimated that the amount of prostatic fluid excreted in the adult was 0.5 to 2 ml. per day. The average amount of fluid obtained by prostatic massage is less than 1 ml.

HYDROGEN ION CONCENTRATION. The pH of prostatic fluid at body temperature is reported by Huggins<sup>9</sup> to be 6.3 to 6.45; Muschat<sup>15</sup> found the pH to range from 7.0 to 7.4 (average, 7.24) at 38° C.

TABLE 214  
CHEMICAL COMPOSITION OF PROSTATIC FLUID  
(Huggins, 1945)<sup>9</sup>

	<i>Resting Fluid</i>
pH.....	6.3-6.45
Specific gravity.....	1.022
	<i>Values per liter of fluid</i>
Water.....	927-936 gm.
Sodium.....	149-158 mEq.
Potassium.....	28.7-61.4 mEq.
Calcium.....	28.7-32.7 mEq.
Chloride.....	34.8-46.1 mEq.
Acid-soluble phosphorus.....	0.65-1.77 mEq.
Carbon dioxide.....	3.1-5.4 mM.
	<i>Values per 100 ml. of fluid</i>
Total nitrogen.....	295-511 mg.
Nonprotein nitrogen.....	30-90 mg.
Total protein.....	2.46-2.64 gm.
Glucose.....	Trace-16.4 mg.
Ascorbic acid.....	0.54 mg.
Citric acid.....	0.48-2.68; 7.0 gm.
Acid phosphatase.....	255-1727 King and Armstrong units
Alkaline phosphatase.....	286 King and Armstrong units
Total lipids.....	62-105 mg.
Cholesterol.....	86-618 mg.

CHEMICAL COMPOSITION. Table 214 summarizes the chemical composition of prostatic fluid. It should be noted that the secretion contains relatively high concentrations of sodium and potassium. The concentration of glucose is low, but the fluid is rich in citric acid. The prostate is rich in spermine, containing 0.1 gm. per 100 gm. of fresh tissue.<sup>8</sup> Most of the spermine of the semen is probably derived from the prostate. Everett<sup>3</sup> indicates that the prostatic concentration of spermine as spermine phosphate is 130 mg. per cent. According to Moore, one of the most important lipids in the prostatic secretion is sphingomyelin.

The acid phosphatase activity of the prostate consistently exceeds that of the liver, kidney, duodenal mucosa and bone.<sup>6, 7</sup> Gutman and Gutman<sup>8</sup>

showed that its concentration increases with age. They reported the following values, expressed in King and Armstrong units:

Birth.....	4.5 units
4 years.....	1.5 units
13 years.....	73 units
Adults.....	522 to 2284 units

The prostatic secretion contains both fibrinolysin and fibrinogenase, the former in much the greater concentration.<sup>10, 11</sup>

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## Chapter 45

### SEMEN EJACULATE OR SEMINAL FLUID

THE SEMEN (ejaculate or seminal fluid) is a mixture of the spermatozoa and the pooled secretions of the glands of the male genital tract. Besides the spermatozoa and the secretions of the epididymis, which together make up less than 5 per cent of the total volume of the ejaculate, the secretions of the vasa, the seminal vesicles, the prostate, the bulbo-urethral (Cowper's) glands and the urethral (Littre) glands are present in the semen.<sup>11</sup> These secretions maintain the fluidity and body of the ejaculate and provide the environmental and nutritional elements necessary for the life of the sperm.

It is not definitely known whether the ejaculate is the product of a haphazard mixture of these several glandular secretions or whether these secretions

TABLE 215  
VOLUME OF EJACULATE

<i>Period of Continence (Days)</i>	<i>Volume (Range in ml.)</i>	<i>Investigator</i>
3.....	3-4	Hotchkiss (1936)
	0.6-9	Hotchkiss, Brunner and Greuley (1938)
	2-6	Mazer and Israel (1941)
7.....	3-6	Meaker (1934)
4-7.....	3-5	Pollak and Joel (1939)
5-7.....	2.5-5	Weisman (1941)
3.....	0.5-5.2	Kaufman (1946)

are brought together to make up the semen in a definite sequence. Broesike<sup>2</sup> did microscopic studies of partitioned ejaculates and described four phases of ejaculation.

1. A pre-ejaculatory emission consisting of one to two clear viscid drops from the bulbo-urethral glands or the urethral glands, or both.

2. The first part of the ejaculate proper is composed primarily of prostatic secretion and is almost free of spermatozoa.

3. The midportion contains the bulk of the sperm.

4. The last part consists mostly of seminal vesicle secretion.

Chemical studies on fractionated ejaculates have confirmed the finding that the first part of the ejaculate consists chiefly of prostatic gland secretion.<sup>8, 10</sup>

Normal semen is colorless, described by some as odorless and by others as having a musty odor, and is gelatinous.

There is no significant storage of sperm in the genital tract. The previous conception that the seminal vesicles act as a storehouse for sperm is no longer

held.<sup>1-10</sup> It has been shown that there is a slow, constant movement of the sperm through the epididymides and the vasa deferentia.<sup>22</sup> The time for this passage is nineteen to twenty-three days.<sup>3</sup> The vasa deferentia empty themselves in two ways: by ejaculation and by a slow, regular flow into the urethra. The latter method explains why sperm may frequently be found in the urine and urethra in the absence of ejaculation.<sup>27</sup> The exact nature of the mechanism of ejaculation in man is unknown.

**VOLUME.** The volume of the seminal fluid expelled at a single ejaculation by a normal person after three to seven days' continence averages 2.5 to 5 ml. (see Table 215).

### PHYSICOCHEMICAL PROPERTIES OF SEMINAL FLUID

**HYDROGEN ION CONCENTRATION.** Hotchkiss,<sup>10</sup> using a method by which the semen was brought into equilibrium with a mixture having the same constituents as alveolar air and the pH computed by a formula based on the amount of sodium bicarbonate present, found that the pH averaged 7.39, or roughly that of the blood. When no precautions are taken against carbon dioxide loss, the specimen becomes somewhat more alkaline, ranging from 7.6 to 8.0. Huggins and Johnson<sup>12</sup> found the pH to range from 7.05 to 7.45, and Goldblatt,<sup>6</sup> from 7.2 to 7.3.

**PHYSICAL PROPERTIES.** The liquefied semen has a characteristic turbidity and is milky-white to yellowish in color. The viscosity of semen has been measured in many ways. Briefly, it should adhere fairly easily to a wooden applicator or to the fingers.

Zagami,<sup>28</sup> quoted by Hotchkiss,<sup>10</sup> found that the relative viscosity (vs. water) was 6.45 (20° C.), the freezing point 0.56° to 0.58° C. (fresh specimen), and the specific electrical conductance 88 to 107 times  $10^{-4}$  mhos (18° C.).

**CHEMISTRY.** Although little is known about the chemical composition of the human spermatozoon, a number of investigators have made chemical analyses of the seminal fluid and the seminal plasma (see Table 216). It should be remembered that the ejaculate is made up of the spermatozoa as well as the combined secretions of all the glands of the genital tract. Weisman<sup>26</sup> states that seminal plasma is 80 to 90 per cent water, 1 to 2 per cent salts, 8 to 10 per cent organic matter, 2 to 6 per cent proteins and 0.21 per cent lipids.

**GLUCOSE.** Huggins and Johnson<sup>12</sup> showed that the semen contains relatively high concentrations of glucose, whereas the prostatic secretion is practically sugar-free. Values for glucose are given in Table 216.

The reducing substance, which most investigators considered to be glucose, appears to be necessary for the maintenance of the normal cellular metabolism of spermatozoa. Its source is primarily from the seminal vesicles.<sup>12, 14, 18</sup> Recently this reducing substance has been found to be d-fructose and not glucose.<sup>18</sup>

**PROTEIN.** Goldblatt<sup>6</sup> found that seminal plasma contains albumin, globulin (traces), mucin (traces), nucleoproteins and thromboplastin, but no peptones. Ross, Moore and Miller<sup>24</sup> recognized three protein components of seminal plasma in electrophoretically pure forms: a nonheat-coagulable protein (protease), a glycoprotein and a water-soluble protein. Spermine phosphate exists in many

tissues in concentrations ranging from 1 to 30 mg. per 100 gm.: semen contains from 90 to 200 mg. per 100 ml.<sup>4</sup> Some semen specimens have a musty odor due to spermidine. Spermine crystals are known as Charcot's crystals. Most of the spermine in the ejaculate comes from the prostate.<sup>4</sup>

CITRATE. Human semen contains 140 to 637 mg. of citrate per 100 ml.<sup>10</sup>

ACID PHOSPHATASE. The acid phosphatase of the semen is derived from the prostate. No other gland of the genital tract secretes a significant amount of acid phosphatase into the seminal fluid. Gutman and Gutman<sup>8</sup> studied the acid phosphatase activity of ten normal subjects from whom at least

TABLE 216  
CHEMICAL COMPOSITION OF SEMINAL FLUID

		<i>Investigator</i>
Protein.....	1.58-180 mg./100 ml.	Hotchkiss (1944)
Nonprotein nitrogen.....	55-80 mg. 100 ml.	Huggins and Johnson (1933)
Amino acids (ext. with butanol).....	31-56 mEq./liter	Hotchkiss (1944)
Urea.....	72 mg./100 ml.	Goldblatt (1933)
Chloride (as NaCl).....	200 mg./100 ml.	Goldblatt (1933)
	230-280 mg./100 ml.	Hotchkiss (1944)
	39-47 mEq./liter	Hotchkiss (1944)
	39-46 mEq./liter	Huggins and Johnson (1933)
Glucose.....	203-369 mg./100 ml.	Huggins and Johnson (1933)
	200-300 mg./100 ml.	Goldblatt (1933)
	380-610 mg./100 ml.	Hotchkiss (1944)
Calcium.....	11.9-32.8 mg./100 ml.	Huggins and Johnson (1933)
	24-25 mg./100 ml.	Goldblatt (1933)
Phosphatase (acid).....	540-4000 K-A units per ml.	Gutman and
(alkaline).....	0.1-1 K-A units per ml.	Gutman (1941)
Phosphorus (inorganic).....	53.3 100 mg./100 ml.	Huggins and Johnson (1933)
	40-50 mg./100 ml.	Goldblatt (1933)
Phosphorus (total acid-soluble).....	95 mg./100 ml.	Goldblatt (1933)
Phosphorus (from diffusate).....	86-101 mg./100 ml.	Hotchkiss (1944)
Phosphorus (spermine).....	13-30 mg./100 ml.	Goldblatt (1933)
Cholesterol.....	80 mg./100 ml.	Goldblatt (1933)
Carbon dioxide.....	11.5-17.7 mM/liter	Huggins and Johnson (1933)
	50 vol. per cent	Goldblatt (1933)
	41-60 vol. per cent	Hotchkiss (1944)
	18.3-26.9 mEq./L.	Hotchkiss (1944)
Lactic acid.....	90-100 mg./100 ml.	Goldblatt (1933)
	36-51 mg./100 ml.	Hotchkiss (1944)
	4-5.6 mEq./liter	Hotchkiss (1944)
Acids extracted with ether*.....	468-603 mg./100 ml.	Hotchkiss (1944)
	52-67 mEq./liter	Hotchkiss (1944)

\* Expressed in terms of lactic acid.

three ejaculates were obtained and found that the values ranged from 540 to more than 4000 units per milliliter of seminal fluid and from 1800 to more than 17,000 King and Armstrong units in the entire specimen.

The acid phosphatase activity varies greatly, but the enzyme level in several ejaculates in any one person is relatively constant. Gutman and Gutman found the activity of the total spermatozoa in each specimen to be as low as 0.4 unit.

ALKALINE PHOSPHATASE. The alkaline phosphatase (pH 9.0), determined in twelve seminal fluid specimens, varied from 0.1 to 1 King and Armstrong units per milliliter.

**HYALURONIDASE.** The follicle cells which surround the newly ovulated ovum of the mammal are embedded in a transparent, viscous gel. This circle of follicle cells must be dispersed and the cementing gel penetrated before the sperm can invade the egg and fertilization take place. McClean and Rowlands<sup>20</sup> showed that hyaluronidase, when allowed to act on recently ovulated ova, dispersed these follicle cells without destroying them or acting on the ovum. They felt that the enzymic action was limited to the gel, and that the gel contains hyaluronic acid, similar to that found in the extracellular cementing substance of connective tissue. These observations have been confirmed by studies on rat ova<sup>17</sup> and mouse ova.<sup>5</sup>

Hyaluronidase is present in normal human semen. Using the mucin clot-preventing test described by McClean (1943), Kurzrok, Leonard and Conrad<sup>16</sup> assayed the hyaluronidase content of human semen. They defined their hyaluronidase unit for semen (H.U.S.) as the amount of enzyme in 1 cc. of semen sufficient to depolymerize 2.5 mg. of hyaluronic acid. They found that 2.5 mg. of highly purified hyaluronidase were necessary to depolymerize 2.5 mg. of hyaluronic acid. Normal semen specimens containing 100 million sperm per milliliter were found to contain 1 hyaluronidase unit, or the equivalent of 2.5 mg. of hyaluronidase per milliliter.

The concentration of hyaluronidase increases with the sperm concentration. Greenberg and Gargill<sup>7</sup> found no hyaluronidase in cases of azoospermia. Kurzrok and his co-workers<sup>16</sup> state that 50 million sperm per milliliter is the critical level below which little if any hyaluronidase is present. They also found that the direct relationship between the enzyme content and sperm population does not necessarily hold in semen specimens with a count of over 100 million per milliliter, in which case the hyaluronidase activity may be normal or high. There is no relation between the hyaluronidase concentration and sperm morphology, per cent motility or type motility.

**CLOTTING AND LIQUEFACTION OF THE EJACULATE.** Normal human semen clots almost immediately on ejaculation, forming a solid mass of such viscosity that the container may be inverted without loss of any material. Softening and partial liquefaction begin within a few minutes, and at the end of fifteen minutes the ejaculate has liquefied, save for a few sago-like or flaky particles which remain for more than an hour.<sup>13, 23</sup> Because of the difficulty of securing semen before clotting, the mechanism by which it coagulates is not clear. Hotchkiss<sup>10</sup> states that the process is probably similar to that of blood clotting, involving the interaction of proteins and thromboplastic substances. Huggins and Neal<sup>13</sup> showed that fibrinogen and fibrinolysin, derived from the prostate gland, are present in the seminal fluid. They were unable to demonstrate thrombin and prothrombin in the liquefied semen. Human semen is poor in fibrinogenase.

Huggins and Neal<sup>13</sup> also observed the lytic phenomenon through a microscope and stated that at three minutes after ejaculation the semen consisted of many interlaced bundles of long, clearly defined, parallel refractile fibers which at four minutes appeared quite swollen. At five minutes the regularity disappears and the fibers are arranged haphazardly. At six minutes they noted a large scale liquefaction with movement visible as many of the fibers were rapidly breaking up. At eight minutes no fibers were seen.

## FORMED ELEMENTS IN SEMINAL FLUID

Besides normal spermatozoa (see Chapter 46), several other cell types will be seen on examining a stained preparation of semen. One of the more detailed of the available descriptions of these cells is that of Pollak and Joel,<sup>23</sup> who report the presence of the following cell types: macrophages, microphages, spermophages, giant cells, Sertoli cells, epithelial cells, leukocytes, prostatic corpuscles, lecithin corpuscles, fat crystals, Böttcher crystals, Chareot crystals, spermine phosphate and testicle cylinders. Weisman<sup>26</sup> listed the nonspermatozoal formed elements in semen as bacteria, leukocytes, red blood cells, mucus, epithelial cells, corpora amylacea and hyaline bodies, starch and talcum granules in condom specimens, crystals and Böttcher crystals.

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## Chapter 46

### SPERMATOOZOA

THE SPERMATOOZON is the mature male germ cell, the unit of male fertility which is necessary for the fertilization of the ovum. The spermatozoa are formed in the testicle after puberty.

The spermatozoa of all forms of animal life have essentially the same structure. Each spermatozoon is a slender, elongated structure with a relatively large head and a flagellate tail (Fig. 100). It is 50 to 70 microns in length. The

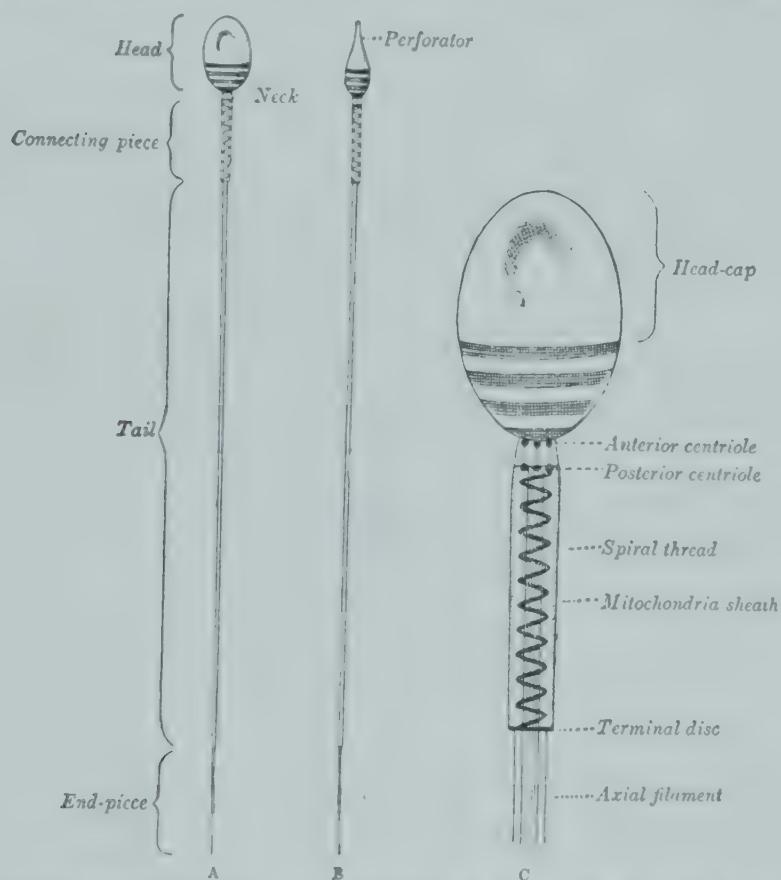


Fig. 100. A human spermatozoon, highly magnified. *A*, Profile view. *B*, Surface view after Retzius. *C*, Diagrammatic representation of the head, neck and connecting piece, more highly magnified (modified from Meves). (Gray, H.: Anatomy, Descriptive and Applied, Longmans, Green and Company.)

normal sperm consists of a head, a neck, a midsection or connecting piece, and a tail. The head is oval and flattened so that it is pear-shaped on profile, and is 3 to 6 microns in length and 2 to 3 microns in width.<sup>13</sup> The neck is the point where the head breaks off after impregnation and consists of two knobs, the anterior and the posterior end knobs. The posterior knob is attached to the axial filament running toward the tail and is the motivating structure of the cell. The connecting piece or midsection is a cylindrical structure about 3 to 6

microns long which connects the head and neck with the tail. The tail makes up 90 per cent of the length of the organism and consists of two parts: the chief piece, 40 to 60 microns long, and the end piece, 5 to 10 microns long.<sup>1, 10</sup>

The spermatozoa make up a negligible part of the volume of the semen. The volume of packed spermatozoa in a rapidly centrifuged specimen of semen is about 0.02 ml.<sup>2</sup> Kurzrok and his co-workers<sup>6</sup> state that the average weight of 1 ml. of spermatic fluid is 1.008 gm., and that the spermatozoa in seminal fluid containing 100 million sperm per milliliter represent 160 mg. of wet weight per milliliter. They estimate that the weight of a single sperm under these conditions is 0.0016 gamma.

**SPERMATOZOAL COUNT.** The sperm count is one method used to determine the relative degree of fertility of an individual male. The count may be expressed as the number of spermatozoa per milliliter or as the total number per specimen. The ejaculate of the normal fertile male after three to seven days of continence contains 60 to 120 million spermatozoa per milliliter, and the total count is 400 to 500 million. In general, the higher the volume of the seminal fluid, the higher the total cell count, although no relation exists between the amount of the ejaculate and the number of spermatozoa per milliliter.

Meaker<sup>3</sup> states that, in his experience, no pregnancy occurred when the sperm count was less than 60 million. McComber and Saunders<sup>7</sup> found four cases of fertile males with a count of less than 60 million in a series of 244 cases. Hotchkiss and his colleagues<sup>4</sup> found counts of less than 50 million per milliliter in eleven cases and counts between 50 million and 100 million in twenty cases of 196 fertile men. In a study of forty fertile males, Kaufman<sup>5</sup> found a count of less than 60 million in six cases. In one case the count was 28 million per milliliter. The first few drops of the ejaculate contain a high spermatozoal count.

The normal spermatozoal count of semen is given in Table 216a.

TABLE 216A

NORMAL SPERMATOZOAL COUNT OF SEMEN

<i>Author</i>	<i>Millions/ml.</i>
Meaker (1934) . . . . .	Minimum, 60
Hotchkiss, Brunner and Grenley (1938) . . . . .	Range, 22.5-544
Pollak and Joel (1939) . . . . .	Range, 60-120
Carey et al. (1934) . . . . .	Minimum, 60
Lane-Roberts et al. (1939) . . . . .	Minimum, 50
Kaufman (1946) . . . . .	Range, 28-225

**MORPHOLOGY.** An adequate number of morphologically normal cells is necessary for fertility. The normal ejaculate will contain 80 per cent normal cells and 20 per cent or less abnormal.<sup>4, 11, 12, 15</sup> Kaufman<sup>5</sup> found the normal forms to average 89.4 per cent. Hotchkiss and his co-workers<sup>4</sup> recognize six main cell types and give the percentages of these cell types as found in the seminal fluid of 200 fertile males (Table 217).

The oval type cell is the morphologically normal spermatozoon. Hotchkiss and his associates divided the tapering cell into three classes and feel that statistically and morphologically those grouped as Tapering I should be con-

sidered as normal cells. After grouping these two types of cells together they found the percentage of normal cells to range from 65.76 to 98.85 per cent and to average 89.81 per cent. They found those classed as Tapering II and III definitely abnormal. Moench<sup>9</sup> found an incidence of 8.5 per cent of these types of cells as the limit for normal fertility.

TABLE 217

## SPERMATOZOAL TYPES

(Hotchkiss, Brunner and Grenley, 1938)<sup>4</sup>

<i>Type of Cell</i>	<i>Average</i>	<i>Range (Per Cent)</i>
Oval.....	84.1	31-98
Tapering.....	9.5	0-59
Round.....	1.7	0-9
Duplicate.....	1.8	0-17
Giant and pinhead.....	0.6	0-8
Amorphous group.....	2.1	0-12

MacLeod<sup>10</sup> reports the presence of an average of 90 per cent normal forms in a morphologic study of semen from 100 apparently normal young men. There is little variation in the morphologic characteristics in health as observed over a period of years in some persons. Moench<sup>9</sup> measured 300 head lengths and emphasized the point that the heads of all spermatozoa in normal semen are relatively uniform in size and that any considerable variation in the head lengths is evidence of morphologic abnormality. He states that in the normal ejaculate there are less than 20 per cent abnormal sperm heads and that the coefficient of variability should be less than eleven.

**MOTILITY.** A normal spermatozoon is actively motile. In order to impregnate the ovum it is necessary that the sperm pass through the entire length of the female genital tract. Only the most active spermatozoa accomplish this requirement. The determination of the type and degree of motility is important in sterility studies and has been found to correlate closely with the relative fertility of the person studied.

Motility is poor during the initial coagulated stage of a fresh specimen. When liquefaction occurs, the sperm activity is well established. Weisman<sup>15</sup> indicates that at the time of examination 10 to 15 per cent dead or nonmotile sperm are found in the normal sample. Most reports on percentage of motility are based on gross methods consisting in an estimation of the percentage of actively motile cells in relation to the total number seen in each field while examining a wet preparation under a 4 mm. microscope objective. Hotchkiss and his co-workers<sup>4</sup> describe active motility as a progressive, space-gaining movement across the microscopic field. Weisman<sup>15</sup> indicates that the forward progress of active spermatozoa is 1 to 4.8 mm. per minute.

Reynolds<sup>13</sup> felt that the type of motility is more important than the degree of movement. He describes three successive and consecutive stages of normal motility: (*a*) progressive vibratile, a rapid forward motion in a straight line with practically no swaying from side to side, in which the sperm swims against a current and usually crosses a field in about five seconds; (*b*) an undulating

tactile motion which follows the first and is characterized by increased swaying and a slower rate; and (c) stationary bunting, which succeeds the second and consists in a tendency on the part of the spermatozoon to push itself against or into any small masses of cells or other materials.

TABLE 218  
MOTILITY OF SPERMATOZOA IN NORMAL SEMEN  
(Weisman, 1941)<sup>15</sup>

Motionless (dead) . . . . .	Less than 15 per cent
Sluggish, struggling motility . . . . .	Less than 15 per cent
Moderate degree of motility . . . . .	At least 75 per cent
Normal swift movements . . . . .	At least 75 per cent

The type, percentage and duration of motility of the spermatozoa are important comparisons. Hotchkiss<sup>3</sup> bases the types of motility on a scale ranging from 0 to 4:

- 0—No action
- 1—Sluggish activity
- 2—Poor to fair activity
- 3—Good activity
- 4—Excellent activity

Hotchkiss found that the average percentage of motility was 60 to 65 per cent. Motility percentage as high as 80 per cent is occasionally found. Kaufman<sup>5</sup> found the estimated motility in normal specimens to average 61 per cent motile cells at the end of three hours, 46 per cent at the end of six hours, and 28 per cent at the end of twelve hours.

Sperm specimens should be examined within three hours after ejaculation to determine the highest degree and percentage of motility. However, a moderate number of sluggishly motile cells may be seen at the end of twenty-four hours on slides kept at room temperature. Cary<sup>1</sup> reported well-sustained motility of sperm in the fluid for eighty to ninety-six hours after coitus.

Single sperm specimens should be studied at regular intervals for at least twenty-four hours. Weisman<sup>15</sup> devised endurance studies on normal sperm. He showed that the minimum period of motility at 20° to 23° C. was twenty-four hours, at 34° to 35° C. eighteen hours. Higher temperatures decreased the period.

CHEMISTRY. Little is known of the chemistry of the mammalian spermatozoan. Hotchkiss<sup>3</sup> indicates that spermatozoa contain both sulfur and phosphorus. Zittle and Zitin<sup>16</sup> have extracted lipids from the heads and tails of spermatozoa. Miescher (quoted by Weisman<sup>15</sup>) showed that the heads are composed essentially of an organic combination of phosphoric acid, or nucleic acid, united with a simple protein.

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Section IX

FEMALE GENITALIA AND REPRODUCTION

(Normal Values in Gynecology and Obstetrics)



## Chapter 47

### FEMALE GENITALIA

THE EXTERNAL genitalia are the parts of the reproductive apparatus that surround the vaginal orifice. Collectively, they are known as the vulva or pudendum (pudendum muliebre). They consist of the mons veneris or pubis; the labia

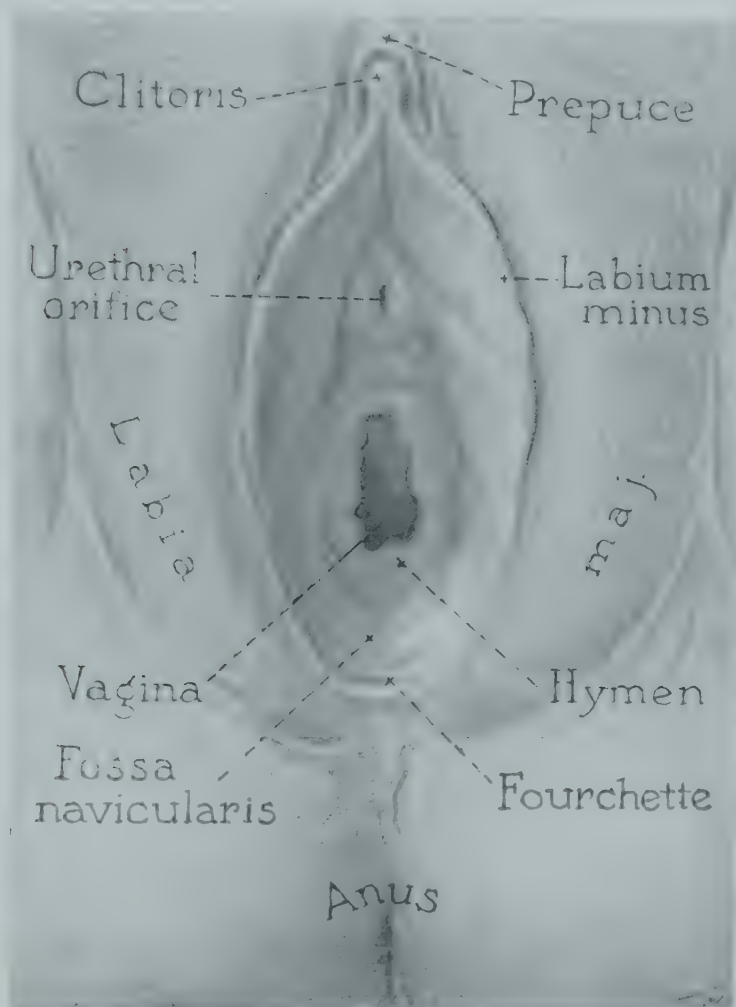


Fig. 101. External genitalia of a nulliparous woman. (Curtis: Textbook of Gynecology.)

majora, the labia minora; the clitoris; the vestibule, the vestibular bulbs and the glands of Bartholin. Figure 101 illustrates the relation of these structures to the vaginal orifice.

### THE VAGINA

The vagina is a fibromuscular tube lined with squamous epithelium. It acts as the main organ of copulation, is a receptacle for the semen and serves as the birth canal.

The vaginal orifice is narrowed by a fold of mucous membrane and con-

nective tissue known as the *hymen*, which varies greatly in shape and consistence. In the newborn it is likely to be redundant and may project slightly. The shape of the hymenal opening is usually round or crescentic, but may assume other forms. It varies in size from a tiny aperture to an orifice that will admit the tip of one and occasionally two fingers. As a result of coitus the hymen is usually torn at several points, but in some instances the elasticity of the tissues will permit coitus without rupture. In a few women the membrane may be so resistant that surgical incision is required to permit coitus. As a result of childbirth the hymen is lacerated more extensively in various places, especially in the posterior parts. The scarred ends or tabs that remain are referred to as the *carunculae myrtiformes*.

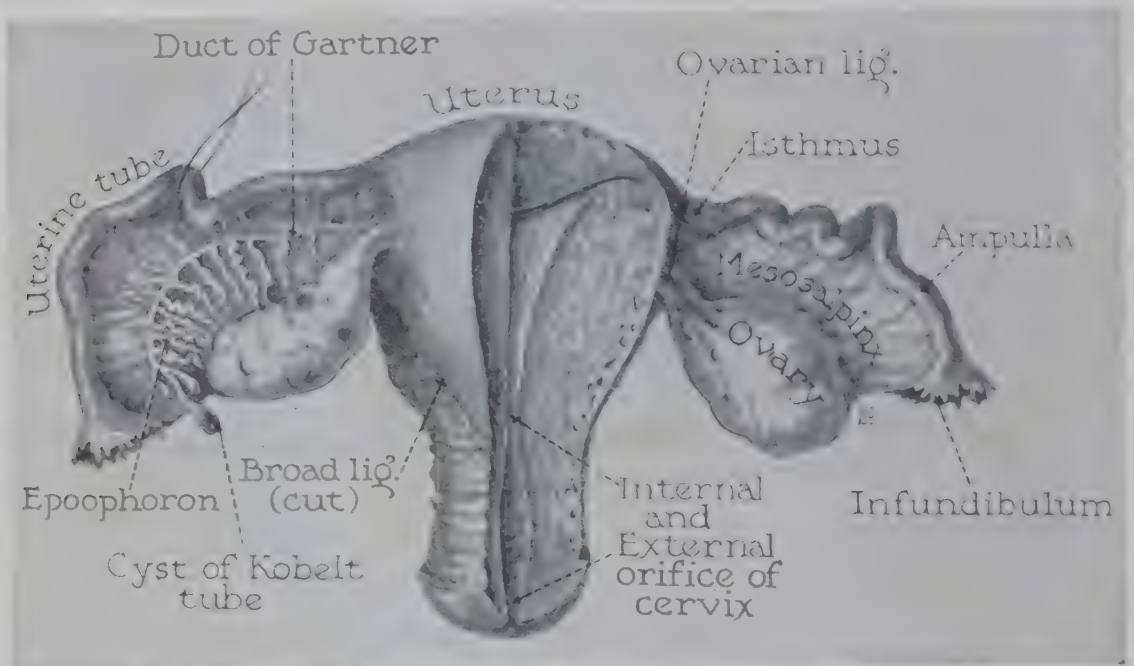


Fig. 102. Internal genital organs, posterior view; fresh specimen from a woman 39 years old. On the left the vestigial ducts are shown within the broad ligament; on the right the uterus has been opened to show the form of its cavity. (Curtis: Textbook of Gynecology.)

The vagina is subject to wide anatomic variations which may not interfere with normal function. The fornices are frequently altered by the position of the cervix, which in 8 to 10 per cent of women is directed anteriorly into the vagina, owing to congenital retroversion of the uterus. Mild degrees of hypoplasia account for shallow fornices, shortened anterior wall, and narrowing of the vaginal canal with no disturbance of function. Withdrawal of estrogenic hormone incident to the menopause results in atrophic changes characterized by narrowing of the entire vagina.

The normal vaginal secretion is usually acid because of the presence of lactic acid. This is governed by the influence of the estrogens and the presence of glycogen and Döderlein's bacilli (lactobacilli). The exact method of production of the lactic acid is not known, although it is generally believed to result from the action of nonbacterial ferments and Döderlein's bacilli (lactobacilli) on the glycogen of the vaginal epithelium.

**HYDROGEN ION CONCENTRATION.** The pH varies at different ages and in different parts of the vagina and also during menstruation and pregnancy. From two to eight years of age the pH usually ranges from 6 to 8. Near puberty it becomes distinctly acid and ranges from 4 to 5 until the menopause, when the values again rise to neutral or slightly alkaline levels as in childhood.

The degree of acidity usually bears a direct relation to the bacterial flora. The pH is lowest when a pure culture of Döderlein's bacilli (lactobacilli) is present and becomes increasingly higher as the bacilli are replaced by other organisms. At birth the vagina is sterile, but within twelve to twenty-four hours a small number of such organisms as staphylococci, enterococci and diphtheroids appear. As early as the third or fourth day these are replaced by Döderlein's bacilli which continue as the vagina remains under the influence of the estrogens derived from the mother. Within a week or ten days these have been completely excreted and the Döderlein's bacilli are replaced by a variety of organisms.

### THE UTERUS

The uterus is a muscular structure which is the organ of menstruation and during pregnancy is the place for nidation and development of the ovum. It is approximately 7 cm. in length, 4 cm. in width and 2.5 cm. in thickness. These dimensions are increased about 1 cm. in women who have borne children. The weight of the virginal uterus ranges between 40 and 50 gm.; the parous uterus is approximately 20 gm. heavier. In the young child the cervix is two times as long as the fundus; in young virgins the two may be equal, while in parous women the corpus may be twice as long as the cervix.

Normally, the fundus of the uterus is flexed forward on the cervix (*anteflexion*). Reversal of this relationship constitutes *retroflexion*. The axis of the entire uterus is turned forward slightly on an imaginary transverse line passing through the internal os (*anteversion*). When the long axis of the uterus is turned backward, the position is referred to as *retroversion*. Anteflexion and anteversion are usually combined, constituting the normal position of the uterus in 85 to 90 per cent of women. In 10 to 15 per cent the opposite is true and the uterus is *retroverted and retroflexed (retroflexioversion)*.

The part of the cervix that protrudes into the vagina is known as the *portio*. The mucosa of the cervical canal is marked by a longitudinal fold running along the anterior and posterior walls and by numerous smaller folds extending upward and outward from the median folds. Numerous compound racemose glands lie beneath the mucosa and open on its surface, where they discharge their thick, glairy, tenacious mucous secretion.

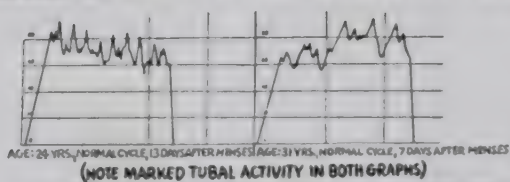
### THE UTERINE TUBES (FALLOPIAN TUBES)

The uterine tubes may vary in length from 8 to 14 cm. (average about 11 cm.). Rubin<sup>12</sup> points out that, measured on x-ray films after injection of contrast medium, the length is much greater (6 to 9 inches) than when the tubes are measured after removal (3 to 4 inches). In the infant and young child

they are relatively longer and more convoluted. The width increases as the outer extremity (ampulla) is approached (5 to 8 mm.), although the width of the isthmus (inner half) remains fairly constant (2 to 3 mm.). The width of the intramural or interstitial part is not more than 0.5 to 1.5 mm.

The structural and the functional activity of the tube is under the influence of the ovarian hormones. The peristaltic waves increase from 3 to 4 per minute immediately after menstruation to 8 or 9 per minute during the time of ovulation.

### (A) TYPICAL GRAPHS OF NORMAL MENSTRUATING WOMEN



### (B) VARIOUS TYPES OF MENOPAUSE GRAPHS

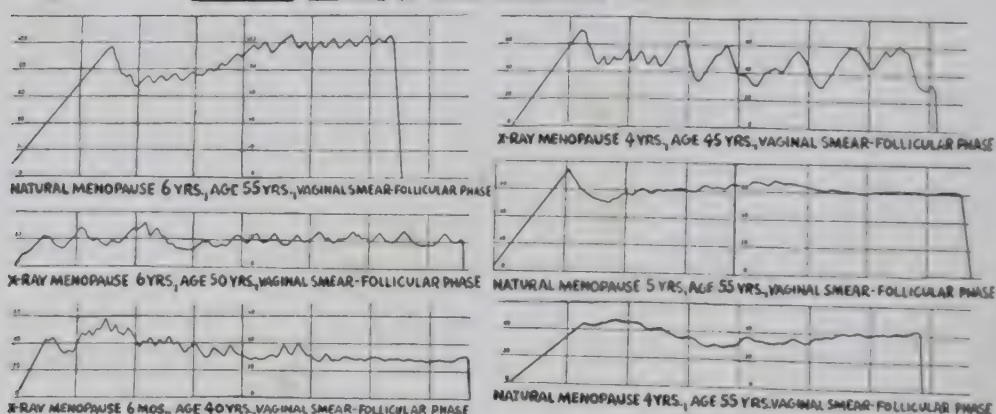


Fig. 103. Common types of graphs, showing tubal contractility. The graphs were obtained with the Rubin insufflation kymographic apparatus by which carbon dioxide, under 15 pou pressure, was introduced into the uterus and tubes through a cannula in the cervix. In normal menstruating women the initial rise pressure (i.e., the pressure required to overcome resistance at the uterotubal junction) varies between 60 and 100 mm. Hg; the tubal contraction rate is between 4 and 6 per minute; and the amplitude of contractions varies from 15 to 50 mm. Hg. During the menopause the average initial rise pressure is below 60 mm. Hg; the average contraction rate is approximately 3 per minute; and the average amplitude of contractions is less than 5 mm. Hg. (Bernstein, P., and Feresten, H.: *Endocrinology*, vol. 26.)

lation. The amplitude of the contractions also increases (see Fig. 103). There is some evidence that the peristaltic waves may be reversed at times, suggesting their influence in aiding ascent of the spermatozoa.

## THE OVARIES

According to Curtis,<sup>5</sup> the average dimensions are 3.6 cm. in length, 1.5 cm. in breadth and 1.2 cm. in thickness. Wide variations occur owing to development of the graffian follicles and the subsequent formation of the corpus luteum, resulting in changes in size from month-to-month or at various times in the menstrual cycle. There is often a marked difference in the size of ovaries in the same person.

## OVULATION

Under the influence of hormonal stimulation from the pituitary a group of primary follicles begin to develop. As a rule only one of these undergoes complete maturation and continues to ovulation. The others cease to develop at various stages and then regress (atresia folliculi). Strassmann<sup>21</sup> has shown that the theca interna forms a cone or wedge which directs the growth of the follicle toward the surface of the ovary. The follicle finally ruptures, and the egg, with some of the surrounding granulosa and the follicle fluid, is extruded (see Fig. 104).

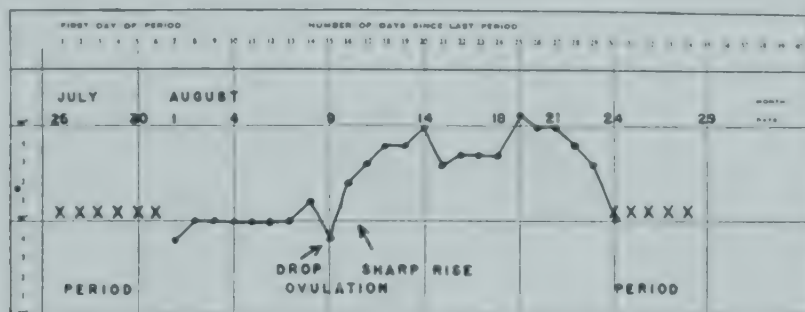


Fig. 104. An ideal temperature graph. The cycle was 30.5-6. Note (1) the relatively low temperature before ovulation; (2) the slight drop on August 9, which occurs at ovulation; (3) the sharp rise after ovulation; (4) the relatively high level after ovulation; and (5) the sharp drop when menstruation begins. (Tompkins, P.: J.A.M.A., vol. 124.)

**TIME OF OVULATION.** Various studies indicate that ovulation is most likely to occur near the midpoint in the menstrual cycle. Rock and Hertig,<sup>18</sup> after studying fertilized and unfertilized human ova, conclude that ovulation takes place about fourteen days before the first day of the next expected menstrual period. Tompkins<sup>22</sup> has used variations in body temperature during various phases of the menstrual cycle to determine ovulation time (see Fig. 104).

TABLE 219  
AGE OF MENARCHEAL GIRLS IN VARIOUS COUNTRIES  
(From Fluhmann, 1939)<sup>7</sup>

Locality	Number of Cases	Average Age at Menarche	Investigator
Scotland.....	10,219	15.037 years	Kennedy
Russia.....	10,000	15.242 years	Grussdeff
Italy.....	31,659	14.968 years	Doria
Norway.....	206	14.57 years	Schreiner
Holland.....	1,800	13 years, 9 months	Bolk
Germany.....	11,550	15.7 years	Schäffer
Germany.....	1,742	14 years, 5 months	Scheibner
Austria.....	1,763	13-13.5 years	Peller and Zimmermann
Poland.....	3,667	15 years, 2 months	Luczynski
India.....	489	13.63 years	Curjel
Brazil.....	2,707	14.17 years	Araujo
Korea.....	424	15 years	Lee
China.....	2,924	14.073 years	Suen-Hsi and Gear
Japan.....	6,354	14 years, 3.7 months	Ishizoka
Japan.....	1,172	14 years, 2.7 months	Yosioka

THE MENSTRUAL CYCLE

Figure 105 illustrates the endocrine influence underlying the menstrual cycle.

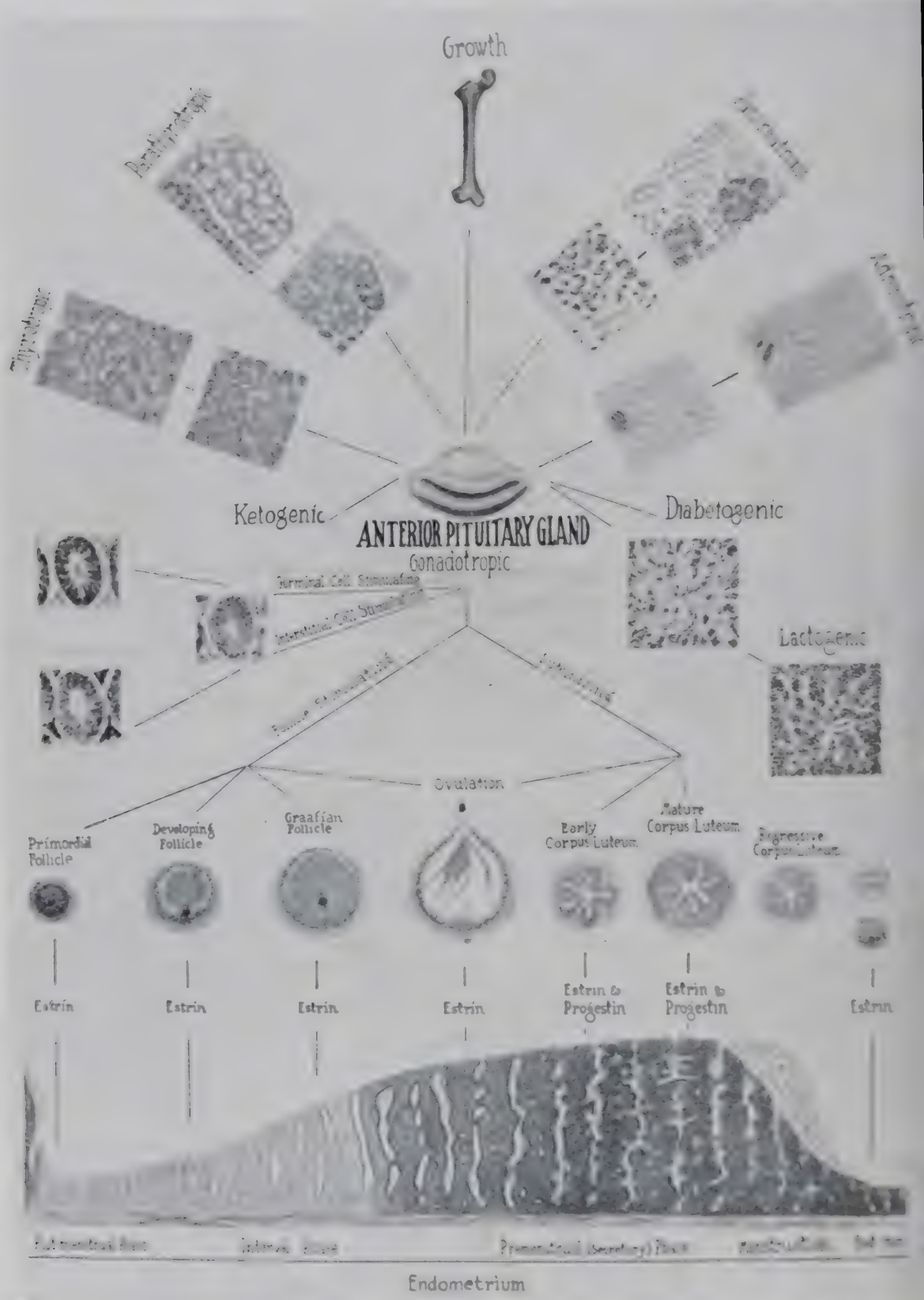


Fig. 105. Anterior pituitary hormones. (Hoffman: Female Endocrinology.)

The flow of menstrual blood from the cervical canal is not continuous, but occurs in tiny spurts or intermittent trickles at intervals of one to fifteen minutes. The most accurate studies indicate a total blood loss of 1 to 5 ounces. Farer and Fowler<sup>2</sup> computed the amount of blood from the iron content of the discharge and found the loss to vary from 9.39 to 207.28 cc. with a mean of 6.7 cc. for one menstrual period.

**ANOVULATORY CYCLE.** Menstruation, or at least regular cyclic bleeding, in the absence of ovulation (first demonstrated by Corner<sup>3</sup> in the monkey and later abundantly proved by Hartman<sup>11</sup>) is now accepted generally as of frequent occurrence in the human.

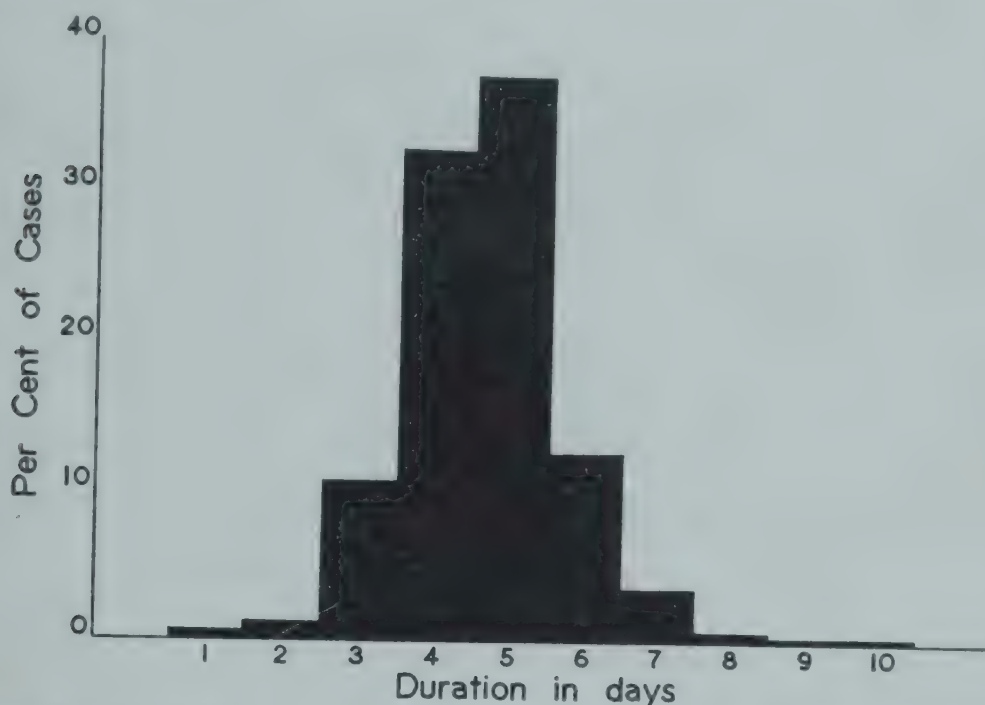


Fig. 106. Distribution of the lengths of 823 menstrual periods in 76 normal young California women. (Fluhmann: Menstrual Disorders.)

### THE MENOPAUSE

The word "menopause" literally refers to the cessation of the menstrual function. However, it is commonly used interchangeably with the broader term "climacteric," which denotes that transitional period in the life of woman characterized by ovarian failure, loss of the child-bearing function, alterations in the hormonal balance and regressive changes in the genitalia.

Menstruation usually ceases between the ages of forty-five and fifty years, the average being about forty-seven years of age. There may be some racial peculiarities. The average menopausal age of Russian women has been found to be 48.7; of French and English women, 45.7; and of Danish women, 44.8 years. The subcommittee of the Medical Women's Federation<sup>4</sup> state that of 197 subjects the menopause appeared in 8 per cent before the fortieth year, in 22.5 per cent in the ensuing five years, in 64.7 per cent between forty-five and fifty-five years, and in less than 5 per cent at fifty-five years and later. permanent cessation of menstruation may occur before the age of forty years

TABLE 220  
VARIABILITY IN LENGTH OF MENSTRUAL CYCLE  
(Hoffman, 1944)<sup>12</sup>

No. of Cases	Nationality	Occupation	Age at Start of Study	Total Number of Cycles	Length of Cycles	Author
56	American	Selected patients		380	Shortest—16, longest—46 days 45 cycles 28 days long; 110 cycles 29–46 days long; 225 cycles 16–27 days long	Foster (1889)
12	German	Housewives	19–39	120	Shortest—20, longest—40 days None absolutely regular; deviations from individual means vary from 2 to 12 days	Issmer (1889)
54	American	College women and industrial workers	17–35	877	Shortest—16; longest—53 days None absolutely regular; deviations from individual means vary from 1 to 26 days	King (1926, 1933)
50	American	Nurses and office workers	12–36	301	Shortest—17, longest—36 days None absolutely regular	Pratt et al. (1929)
200	American	Selected patients			Variable. Flow appears from 5 days before to 10 days after expected time	Geist (1930)
131	American	Student nurses		1522	Shortest—13, longest—84 days	Allen (1933)
100	American-Jewish	Orphanage girls	11–16	3140	Shortest—7, longest—256 days None absolutely regular. Deviations from individual means vary from 6 to 211 days	Engle and Shelesnyak (1934)
76	American	Student nurses	18–27	747	Shortest—11, longest—144 days None absolutely regular. Deviations from individual means vary from 2 to 69 days	Fluhmann (1934)
416	German	Selected patients	16–40		Shortest—14, longest—56 days Majority 26–30 days	Weinstock (1934)
51	Hungarian	University students	18–34	386	Shortest—20, longest—91 days None absolutely regular; average 30 days	Scipiades (1935)
202	American-Canadian	Housewives	20–49	2449	Shortest—15, longest—101 days Deviations from individual means vary from 1 to 53 days	Latz and Reiner (1935) (1937)
479	British	Professional and other women	13–51	6000	Majority (90%) 25 to 36 days None absolutely regular. Most vary 8 to 9 days	Gunn et al. (1937)

(climacterium praecox), but the possibility of underlying pathologic lesion must always be considered. Instances of delayed menopause (climacterium tardum) have been reported, but after the age of fifty-five years they are probably due to unrecognized organic disease. Heredity probably plays an important role, but age of onset and child-bearing have little influence on the cessation of menstruation.

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## Chapter 48

# REPRODUCTION

## PREGNANCY

PREGNANCY is associated with extensive changes in the general organism as well as in the genitalia. It is the purpose of this chapter to outline these changes as they occur in normal pregnancy.

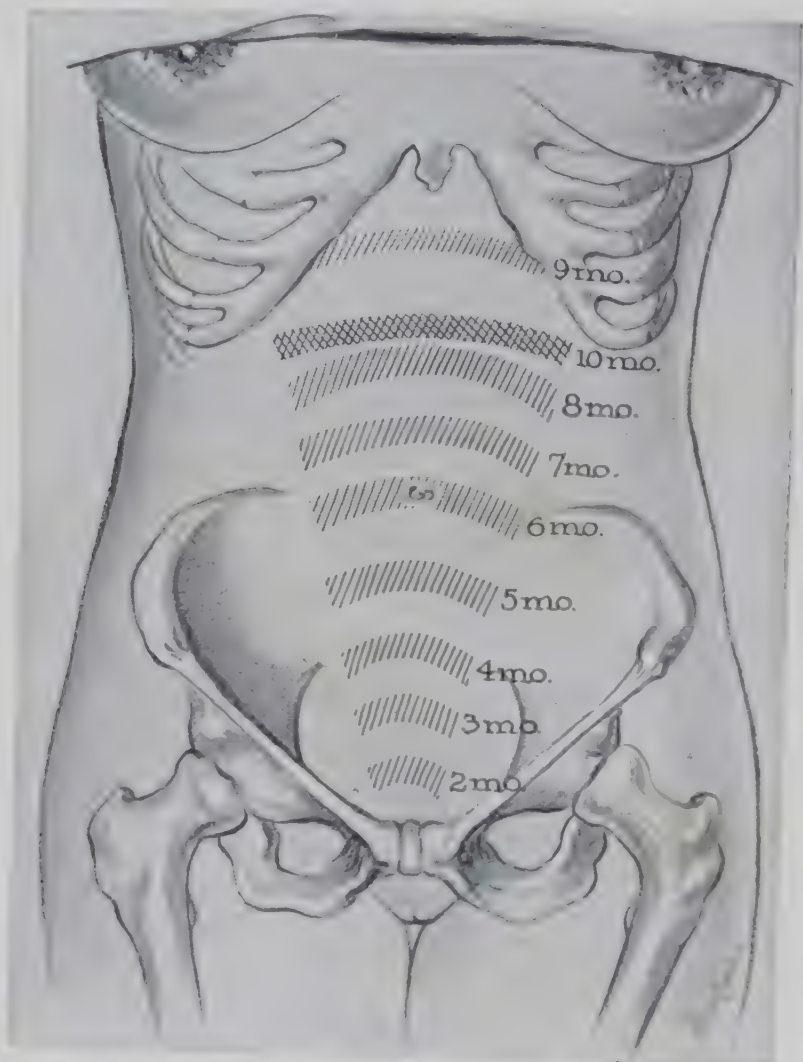


Fig. 107. The height of the fundus at the different months of pregnancy. (DeLee and Greenhill: Principles and Practice of Obstetrics.)

### CHANGES IN THE GENITAL ORGANS AS A RESULT OF PREGNANCY

**THE VAGINA.** The vagina undergoes true hypertrophy: the mucosa thickens and the elastic and muscle fibers hypertrophy.

**THE UTERUS.** The uterus enlarges as the result of hypertrophy of the muscle fibers and an increase in the elastic and the connective tissue elements.

New muscle fibers are thought to form during the first three or four months and perhaps throughout pregnancy. Stander<sup>22</sup> states the average size of the uterus at term as about 32 by 24 by 22 cm. with a corresponding increase in weight to 1000 gm.

**THE FALLOPIAN TUBES.** The fallopian tubes become stretched out and hang almost perpendicularly at the sides of the uterus, but there is no hypertrophy of the muscular elements.

**THE OVARY.** Ovulation ceases during pregnancy, and the single corpus luteum persists in one ovary, where it is essential during the first three or three

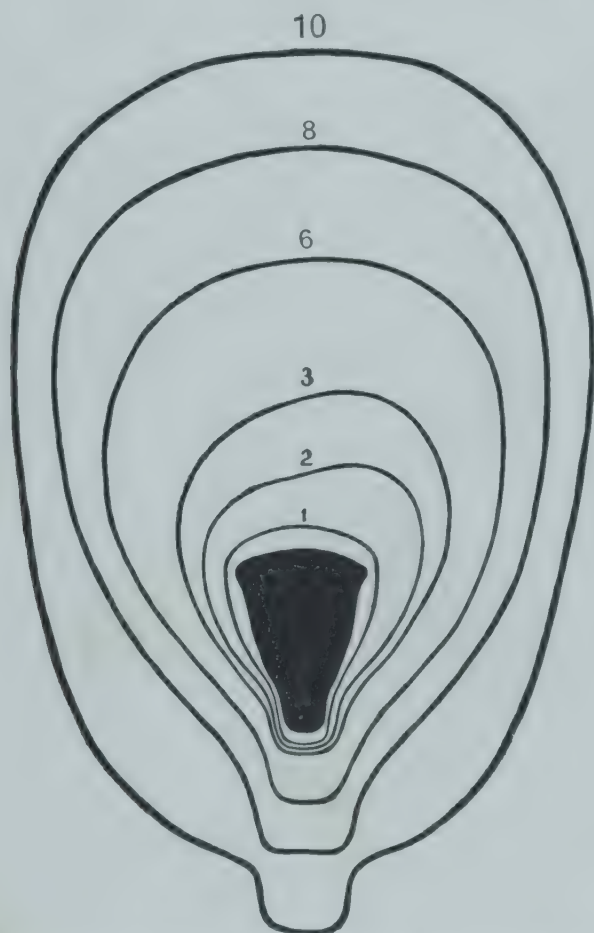


Fig. 108. The uterus at successive months. (DeLee and Greenhill: Principles and Practice of Obstetrics.)

and one-half months. However, many follicles undergo a certain development of the cells of the theca folliculi. These cells may be prominent in the ovary and have been spoken of as the interstitial gland.

**THE BREASTS.** Marked changes in the breasts characterized by increased vascularization and hypertrophy of all the elements are under the influence of the hormones of the ovary and the pituitary.

## CHANGES IN THE HEART AND BLOOD DURING PREGNANCY

**THE HEART.** The question whether the heart actually hypertrophies during pregnancy is unsettled, although most authors agree that there is a tendency

to increased weight as pregnancy progresses. On the basis of Dreyse's<sup>10</sup> data the weights of 67 hearts of pregnant and puerperal women, Jensen<sup>11</sup> concludes: "1. that there is a tendency for the heart to increase in size within normal limits as pregnancy advances; 2. that the ratio of heart weight to body weight remains fairly constant; 3. that the evidence in support of this view is old and needs amplification by means of more recent and plentiful material; and 4. that certain animal experiments indicate that the heart may be able to accommodate itself to increased work without hypertrophying, namely, by increasing its capillary circulation."



Fig. 109. The uterus at successive months, from the side. (DeLee and Greenhill: *Principles and Practice of Obstetrics*.)

The electrocardiogram shows a deep Q 3 due to elevation of the diaphragm and alteration in the shape of the T waves; lead III and sometimes lead II may be inverted. There are also changes in the precordial leads.

**BLOOD PRESSURE.** Table 221 shows the changes in blood pressure during pregnancy.

**TOTAL BLOOD VOLUME.** There is an increase during pregnancy of about 23 per cent, or from an average of 75 to 100 ml. per kilogram of body weight before pregnancy, to one of 90 to 120 ml. by the end of pregnancy.<sup>1</sup> The blood and plasma volume begin to increase in the first trimester, and by the thirteenth week the gain amounts to 16 per cent and 18 per cent, respectively. At term the plasma volume is increased 25 per cent and the blood volume 23 per cent. The

TABLE 221  
FREQUENCY DISTRIBUTION OF SYSTOLIC AND DIASTOLIC BLOOD PRESSURES IN NORMAL PREGNANT PATIENTS  
(Dieckmann, 1941)<sup>3</sup>

<i>Weeks of Gestation</i>	<i>Systolic (Mm. Hg)</i>						<i>Diastolic (Mm. Hg)</i>					
	80-89	90-99	100-109	110-119	120-129	130-139	40-49	50-59	60-69	70-79	80-89	90-99
5-8.....	2	3	8	8	4	1	2	5	14	4	1	
9-12.....	2	14	20	15	14	1	1	10	29	23	3	
13-16.....	5	24	26	29	14	5	1	20	44	31	7	
17-20.....	7	26	37	31	19	3	..	21	61	34	7	
21-24.....	8	26	46	42	12	1	2	27	59	39	7	1
25-28.....	5	25	51	40	21	1	..	25	60	49	7	2
29-32.....	6	26	40	55	19	3	..	22	63	52	12	
33-36.....	1	18	43	52	27	5	..	13	57	48	25	3
37-40.....	2	10	31	50	35	6	..	5	36	59	29	5
6 wk. post partum.....	3	11	30	45	31	12	..	5	30	59	33	5

highest point being first reached at the fifth month. Keith and his co-workers found the average decrease in blood volume after delivery to be 1100 ml. from seven to ten days after delivery. Most of the decrease is in the volume of the plasma, and, since there is no corresponding decrease in the total corpuscular volume, the postpartum increase in the red cell count is partly due to blood concentration. Richter and his associates<sup>1</sup> found at eight to ten days after delivery a mean reduction in the total blood volume of 1871 ml., of which 1327 ml. were plasma.

**PACKED CELL VOLUME (HEMATOCRIT).** There is about a 14 per cent decrease in the percentage of packed cell volume during pregnancy, because of the

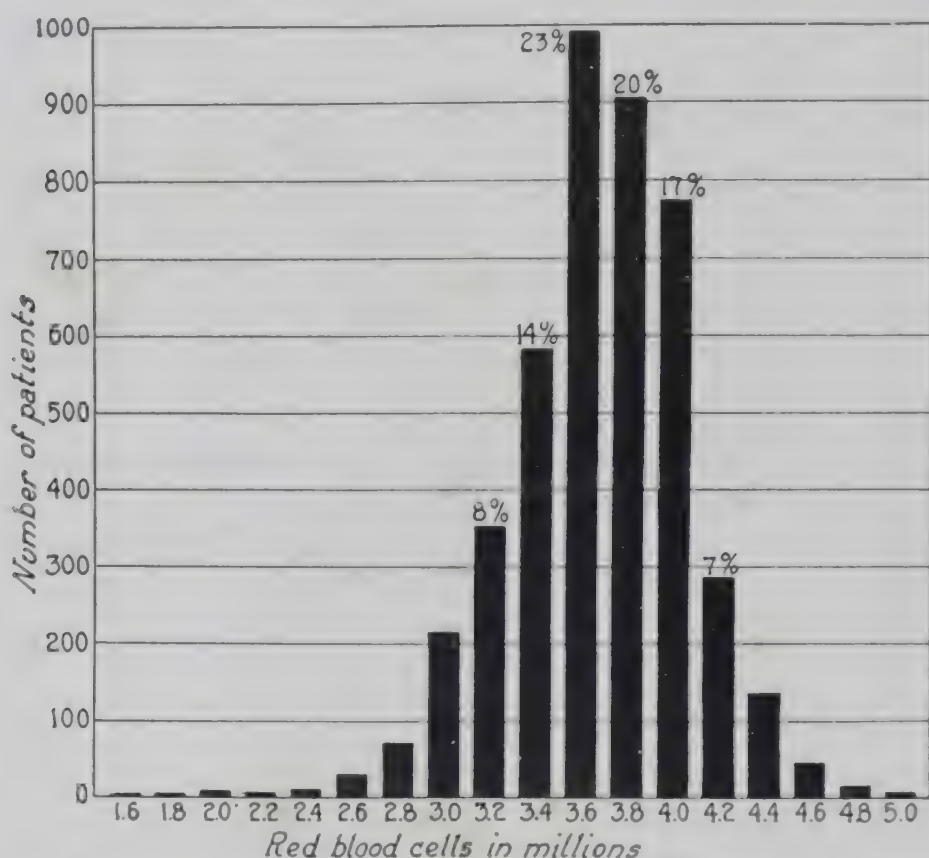


Fig. 110. Graph illustrating the frequency distribution for erythrocytes (4345 patients). (Adair, F. L., Dieckmann, W. J., and Grant, K.: *Am. J. Obst. & Gynec.*, vol. 32.)

hydremia. The total corpuscular volume in the body is, however, increased about 25 per cent. The mean corpuscular volume is usually within the normal range for nonpregnant women (see Table 222).

**ERYTHROCYTE COUNT.** The increase in the blood volume during pregnancy with a proportionally greater increase in plasma than in cells results in a diminution of the number of erythrocytes per cubic millimeter of blood. In view of the increase in blood volume, the total number of erythrocytes in the body is actually increased. The counts are lowest usually in the third trimester. A true anemia should not be considered to exist unless the red cell count falls below 3,500,000, or the mean corpuscular volume and hemoglobin fall below the norms for pregnant women (see Table 222). To allow for individual variations, the

blood should be examined in the early stage of the pregnancy so that subsequent counts can be compared with the original. It may be evident whether or not the decrease is in proportion to the expected change because of the hydremia.

**HEMOGLOBIN.** During pregnancy there is a decrease in hemoglobin generally parallel to the decrease in the erythrocyte count and due to the same factors causing this decrease (Table 222). Actually, the total amount of hemo-

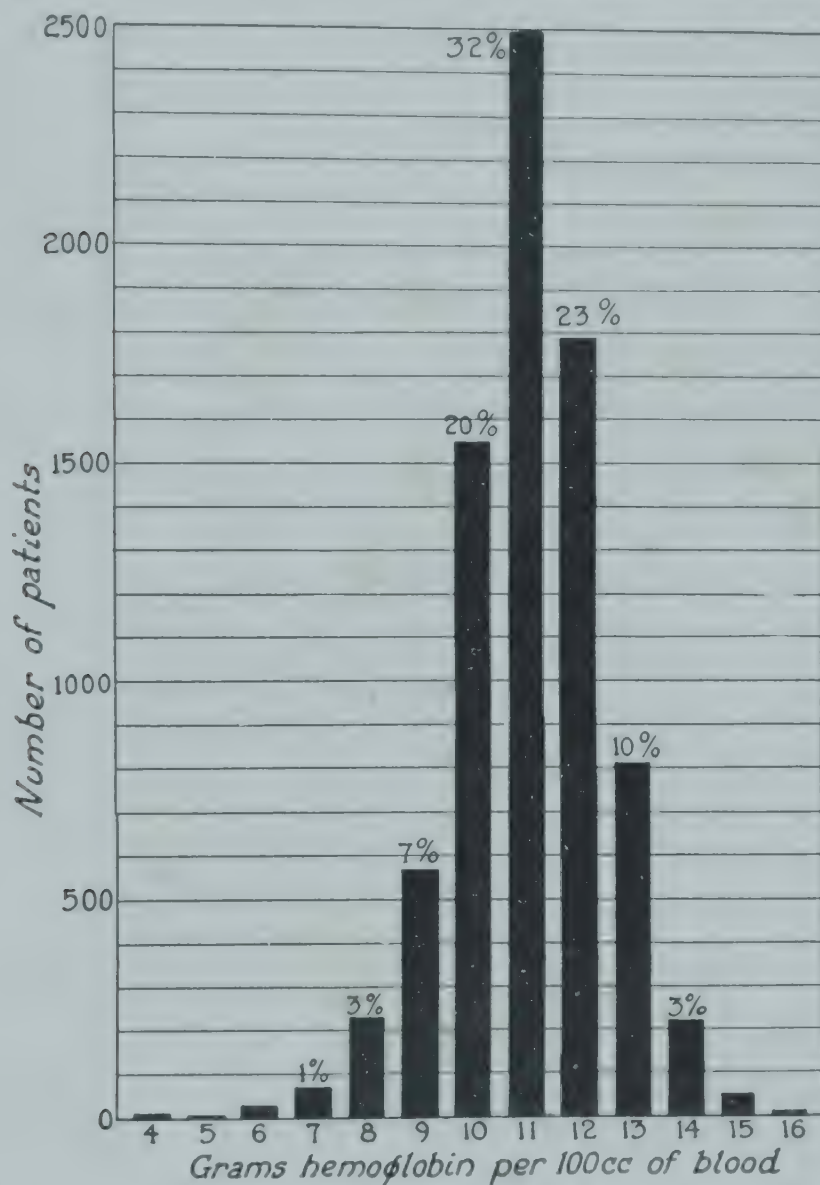


Fig. 111. Graph illustrating the frequency distribution for hemoglobin (7835 patients). Adair, F. L., Dieckmann, W. J., and Grant, K.: *Am. J. Obst. & Gynec.*, vol. 32.

globin in the body is increased. The mean corpuscular hemoglobin is within the range for nonpregnant women (page 46).

**SEDIMENTATION RATE OF ERYTHROCYTES.** An increase in the rate takes place progressively with each month of normal pregnancy. In the ninth month the rate is approximately five times the values for the average normal nonpregnant woman. The rate returns to normal by the fourth week after delivery.<sup>14</sup>

**RETICULOCYTES.** The reticulocytes are said to be increased during normal pregnancy.

LEUKOCYTES. A slight leukocytosis due principally to an increase in polymorphonuclear neutrophils takes place in pregnancy. The counts are usually between 10 and 12 thousand per cubic millimeter. During the third trimester

TABLE 222  
NUMBER OF ERYTHROCYTES, PER CENT PACKED CELL VOLUME, HEMOGLOBIN, MEAN CORPUSCULAR CONSTANTS AND INDICES OF THE BLOOD OF PREGNANT WOMEN AT DIFFERENT STAGES OF PREGNANCY  
(Adapted from Dieckmann and Wegner, 1934)<sup>9</sup>

	Antepartum			Post Partum	
	10-15 Weeks	26-35 Weeks	36 Weeks to Term	2-6 Days	10-15 Days
Erythrocytes (million/cm.)					
Range*.....	3.61-5.29	3.12-4.64	3.45-5.05	3.05-4.69	3.00-5.25
Packed cell volume (per cent)					
Range.....	33.0-46.2	28.7-45.1	30.5-46.1	28.4-43.6	26.1-48.1
Hemoglobin (gm./100 ml.)					
Range.....	10.2-17.0	8.9-16.1	9.8-16.2	8.5-15.7	7.9-15.9
Mean corpuscular volume (c.micr.)					
Average.....	90	94	89.9	93.8	94
Mean corpuscular hemoglobin					
Average.....	30.4	29.7	28.6	.....	27.2
Mean corpuscular hemoglobin concentration (per cent)					
Average.....	34.2	32.9	32.5	.....	31.1

\* Ranges = plus or minus 2 × SD.

TABLE 223  
PACKED CELL VOLUME AND HEMOGLOBIN IN THE BLOOD OF PREGNANT WOMEN AT VARIOUS TIMES  
(Adapted from Oberst and Plass, 1936)<sup>18</sup>

	Packed Cell Volume (Per Cent)	Hemoglobin (Gm./100 ml. of Blood)
	Range	Range
Late normal pregnancy (primigravidas).....	29-42	9-14
Late normal pregnancy (multigravidas).....	30-37	10-12
Early in labor.....	35-44	11-14
At delivery.....	37-47	12-16
Post partum (7-9 days after delivery).....	39-53	12-17
Umbilical cord blood.....	42-60	15-18

there may be a further increase, and during labor itself counts as high as 20,000 to 30,000 have been observed. According to Carey and Litzenberg,<sup>4</sup> most of the leukocyte counts in pregnancy fall between 10,000 and 11,000.

PLATELETS. There is no general agreement as to the number of platelets in the blood during pregnancy. A decrease seems to occur in the first stage of

TABLE 224  
BLOOD CHEMISTRY IN PREGNANCY\*  
(Data from Dieckmann, 1941)<sup>8</sup>

	Range
Albumin-globulin ratio.....	1.0-1.8
Albumin.....	2.9-4.3 gm./100 ml.
Calcium.....	8.6-9.5 mg./100 ml.
Chlorides (as NaCl).....	494-612 mg./100 ml.
Cholesterol.....	Increased
Carbon dioxide.....	45-58 volumes per cent
Fatty acids.....	362 mg./100 ml.
Globulin.....	2.3-3.8 gm./100 ml.
Neutral fat.....	154 mg./100 ml.
Phosphatase.....	Increased during labor
Phospholipid.....	195 mg./100 ml.
Protein.....	5.8-7.9 gm./100 ml.

\* The substances not included were usually found to be the same as in nonpregnant women. For normal data for blood chemistry, see Section III. For glucose tolerance tests, see Chapter 18. For lipids during pregnancy, see page 120.

TABLE 225  
CONDUCTIVITY, TOTAL BASE, CARBON DIOXIDE, CONTENT, pH AND SODIUM CHLORIDE CONCENTRATION IN THE SERUM OF PREGNANT WOMEN AT DIFFERENT STAGES OF PREGNANCY  
(Adapted from Dieckmann and Wegner, 1934)<sup>9</sup>

	Ante Partum			Post Partum	
	10-15 Weeks	25-35 Weeks	36 Weeks to Term	2-6 Days	10-15 Days
Conductivity (per cent of NaCl)					
Range*.....	0.756-0.804	0.750-0.810	0.645-0.801	0.763-0.819	0.762-0.802
Total base (millimols)					
Range.....	148.7-160.5	144-160.4	138.6-162.6	146.7-159.1	140.7-166.3
CO <sub>2</sub> content of serum (per cent vol./100 ml.)					
Mean.....	53	54	53	54	55
pH of serum					
Mean.....	7.4	7.39	7.39	7.39	7.39
NaCl (serum) (mg./100 ml.)					
Range.....	577.3-629.3	583.7-630.9	573.7-636.5	571.7-622.9	585.6-629.4

\* Range = plus or minus 2 × SD.

labor with a return to the base level during the second stage. During the first and occasionally the second day after delivery there is a slight decrease, followed by an increase which reaches its maximum about eight days after delivery.

COAGULATION TIME. The coagulability of the blood in women before, during and after labor is within the limits of normal. Falls<sup>15</sup> found the average clotting time of venous blood in glass tubes to be five minutes at term before labor during labor 4.75 minutes, and post partum 5.3 minutes. Blood collected from

TABLE 226  
PLASMA FIBRIN, SERUM PROTEIN AND PLASMA CHOLESTEROL OF PREGNANT WOMEN AT DIFFERENT STAGES OF PREGNANCY  
(Adapted from Dieckmann and Wegner, 1934)<sup>9</sup>

	Ante Partum			Post Partum	
	10-15 Weeks	26-35 Weeks	36 Weeks to Term	2-6 Days	10-15 Days
Plasma fibrin (mg./100 ml.)					
Range*.....	200-600	130-730	200-720	250-850	230-630
Serum protein (gm./100 ml.)					
Range.....	5.9-7.5	5.6-7.2	5.7-7.3	4.9-7.3	5.8-7.8
Plasma cholesterol (mg./100 ml.)					
Range.....	112.5-426.5	180.6-334.6	137.1-525.1	157.7-463.7	102.1-512.1

\* Range = plus or minus 2 × SD.

TABLE 227  
PLASMA PROTEIN AND SPECIFIC GRAVITY OF BLOOD OF PREGNANT WOMEN AT DIFFERENT TIMES  
(Adapted from Oberst and Plass, 1936)<sup>18</sup>

	Plasma Protein (Gm./100 Ml.)		Specific Gravity of Blood	
	Minimum	Maximum	Minimum	Maximum
Late normal pregnancy (primigravidas)...	5.0	7.2	1.030	1.040
Late normal pregnancy (multigravidas)...	5.0	7.2	1.033	1.040
Early in labor.....	5.9	6.9	1.033	1.046
At delivery.....	6.4	7.0	1.037	1.047
Post partum (7-9 days after delivery).....	6.2	7.6	1.039	1.050
Umbilical cord blood.....	5.3	6.7	1.040	1.051

the umbilical vein of the newborn of these mothers clotted in the average time of 4.5 minutes. The average clotting time of cutaneous blood of 100 pregnant women, most of them in the last months of pregnancy, was 4.78 minutes, with a maximum of seven and one-half and a minimum of three minutes (Burker's method).<sup>16</sup>

**PROTHROMBIN.** Most workers consider the prothrombin level in the mother to be normal. Plum<sup>22</sup> and Thordarson,<sup>23</sup> however, have found it high.

**BLOOD CHEMISTRY.** Table 224 gives the range of the chemical components which may deviate from the usual normal range during pregnancy. Those not listed differ little, if any, from the values given in Table 117.

**GLUCOSE TOLERANCE.** Results of oral glucose tolerance tests during pregnancy are similar to those obtained in normal adults, except that the return to the fasting concentration of blood glucose may be somewhat prolonged (see Table 79a, p. 141).

BODY WEIGHT CHANGES DURING PREGNANCY

Stander and Pastore's<sup>23</sup> statistics on average weight gain and loss based on 2935 patients are as follows:

Weight gain from sixth to fortieth week.....	24.10 per cent—13.9 kg.
Loss during week before labor.....	1.58 per cent— 1.11 kg. ✓
Loss during delivery.....	7.74 per cent— 5.35 kg. ✓
Loss during first ten days of puerperium.....	3.77 per cent— 2.30 kg. ✓
Loss during last five weeks of puerperium.....	1.11 per cent— 0.68 kg.

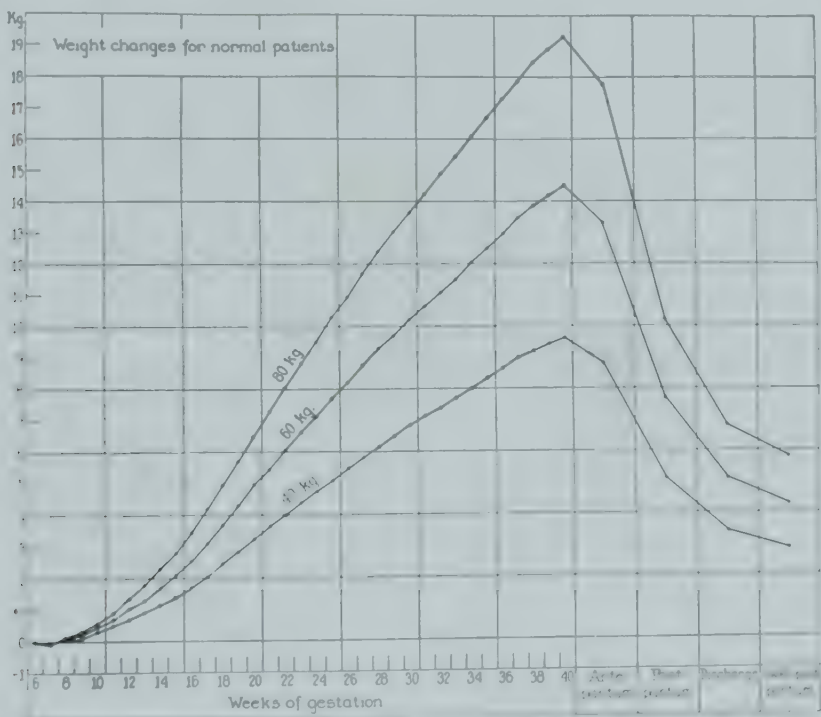


Fig. 112. Normal weight changes for patients weighing 40, 60 and 80 kg. Stander, H. J., and Pastore, J. B.: *Am. J. Obst. & Gynec.*, vol. 39.)

They concluded that primipara as a rule do not return to their original weight after pregnancy. There is no difference in weight changes between primipara and multipara.

ENDOCRINES IN PREGNANCY

The mean weight of the pituitary gland of women between the ages of sixteen and forty-nine years was found to be 0.6112 gm., while in twenty-four pregnant women the mean weight was 0.7074 gm., indicating an increase in

pregnancy of 0.1133 gm. The enlargement was limited almost entirely to the anterior lobe.

The thyroid gland is definitely enlarged during pregnancy, owing to hyperplasia of the glandular part and to the storage of colloid. No accurate weight are available.

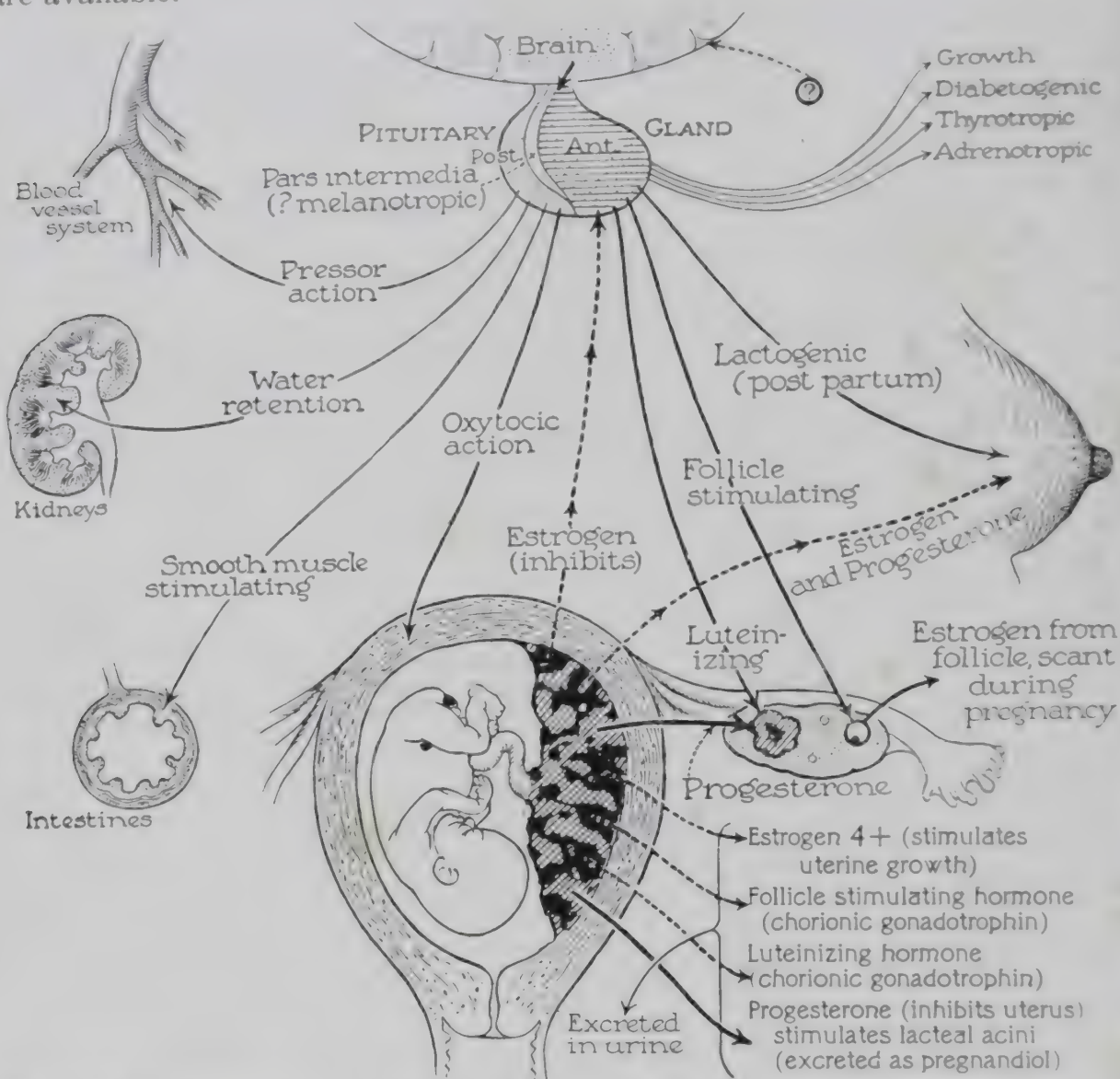


Fig. 113. Endocrine relations of pituitary gland and placenta in normal pregnancy. DeLee and Greenhill: Principles and Practice of Obstetrics.)

The cortex of the adrenal glands is increased during pregnancy, owing to an increase in the cells of the zona fasciculata (see also Chapter 57).

#### BASAL METABOLISM IN PREGNANCY

See Chapter 61, on Basal Metabolism (Fig. 211).

#### UREA CLEARANCE

See Table 188 (p. 332).

#### ESTIMATION OF CONFINEMENT DATE

The normal gestation period is about 273 to 280 days. The exact time has never been determined, but it is stated that it lasts 270 days from the fruitful

CONFINEMENT TABLE (ELY)\*

January <i>October</i>	1 8	2 9	3 10	4 11	5 12	6 13	7 14	8 15	9 16	10 17	11 18	12 19	13 20	14 21	15 22	16 23	17 24	18 25	19 26	20 27	21 28	22 29	23 30	24 31	25 1	26 2	27 3	28 4	29 5	30 6	31 7	January <i>November</i>
February <i>November</i>	1 8	2 9	3 10	4 11	5 12	6 13	7 14	8 15	9 16	10 17	11 18	12 19	13 20	14 21	15 22	16 23	17 24	18 25	19 26	20 27	21 28	22 29	23 30	24 1	25 2	26 3	27 4	28 5				February <i>December</i>
March <i>December</i>	1 6	2 7	3 8	4 9	5 10	6 11	7 12	8 13	9 14	10 15	11 16	12 17	13 18	14 19	15 20	16 21	17 22	18 23	19 24	20 25	21 26	22 27	23 28	24 29	25 30	26 31	27 1	28 2	29 3	30 4	31 5	March <i>January</i>
April <i>January</i>	1 6	2 7	3 8	4 9	5 10	6 11	7 12	8 13	9 14	10 15	11 16	12 17	13 18	14 19	15 20	16 21	17 22	18 23	19 24	20 25	21 26	22 27	23 28	24 29	25 30	26 31	27 1	28 2	29 3	30 4		April <i>February</i>
May <i>February</i>	1 5	2 6	3 7	4 8	5 9	6 10	7 11	8 12	9 13	10 14	11 15	12 16	13 17	14 18	15 19	16 20	17 21	18 22	19 23	20 24	21 25	22 26	23 27	24 28	25 29	26 30	27 1	28 2	29 3	30 4	31 5	May <i>March</i>
June <i>March</i>	1 8	2 9	3 10	4 11	5 12	6 13	7 14	8 15	9 16	10 17	11 18	12 19	13 20	14 21	15 22	16 23	17 24	18 25	19 26	20 27	21 28	22 29	23 30	24 31	25 1	26 2	27 3	28 4	29 5	30 6		June <i>April</i>
July <i>April</i>	1 7	2 8	3 9	4 10	5 11	6 12	7 13	8 14	9 15	10 16	11 17	12 18	13 19	14 20	15 21	16 22	17 23	18 24	19 25	20 26	21 27	22 28	23 29	24 30	25 1	26 2	27 3	28 4	29 5	30 6	31 7	July <i>May</i>
August <i>May</i>	1 8	2 9	3 10	4 11	5 12	6 13	7 14	8 15	9 16	10 17	11 18	12 19	13 20	14 21	15 22	16 23	17 24	18 25	19 26	20 27	21 28	22 29	23 30	24 31	25 1	26 2	27 3	28 4	29 5	30 6	31 7	August <i>June</i>
September <i>June</i>	1 8	2 9	3 10	4 11	5 12	6 13	7 14	8 15	9 16	10 17	11 18	12 19	13 20	14 21	15 22	16 23	17 24	18 25	19 26	20 27	21 28	22 29	23 30	24 1	25 2	26 3	27 4	28 5	29 6	30 7		September <i>July</i>
October <i>July</i>	1 8	2 9	3 10	4 11	5 12	6 13	7 14	8 15	9 16	10 17	11 18	12 19	13 20	14 21	15 22	16 23	17 24	18 25	19 26	20 27	21 28	22 29	23 30	24 31	25 1	26 2	27 3	28 4	29 5	30 6	31 7	October <i>August</i>
November <i>August</i>	1 8	2 9	3 10	4 11	5 12	6 13	7 14	8 15	9 16	10 17	11 18	12 19	13 20	14 21	15 22	16 23	17 24	18 25	19 26	20 27	21 28	22 29	23 30	24 31	25 1	26 2	27 3	28 4	29 5	30 6		November <i>September</i>
December <i>September</i>	1 7	2 8	3 9	4 10	5 11	6 12	7 13	8 14	9 15	10 16	11 17	12 18	13 19	14 20	15 21	16 22	17 23	18 24	19 25	20 26	21 27	22 28	23 29	24 30	25 1	26 2	27 3	28 4	29 5	30 6	31 7	December <i>October</i>

\* The upper date represents the first day of the last menstrual period, and the date below is the confinement date.

coitus. The date of confinement is estimated on an average by using *Naegle's rule*, which states: "The estimated date of confinement will occur nine months and seven days after the onset of the last normal menstrual period." The calculation is carried out by taking the date of the first day of the last normal period, subtracting three months and adding seven days. For example, if the last period began on September 20th, the estimated date of confinement is June 27th of the following year.

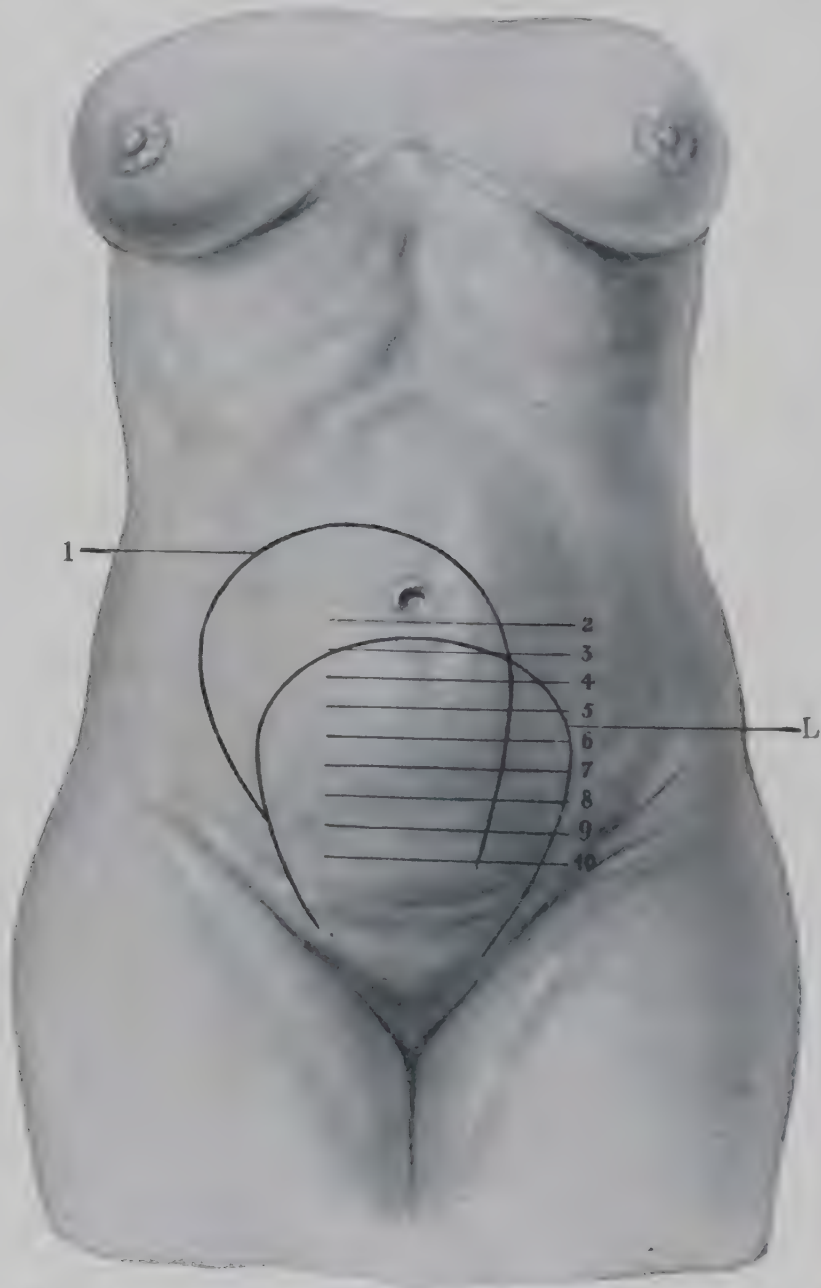


Fig. 114. Height of uterus post partum, the bladder empty. L, Immediately after labor; 1, first day; 2, second day; and so on. (DeLee and Greenhill: Principles and Practice of Obstetrics.)

### LABOR

**NORMAL DURATION OF LABOR.** The mean duration of labor in both primipara and multipara is longer in Negro than in white women. The average primiparous labor in the white woman lasts 16.57 hours, as contrasted with

17.66 hours in the Negro race, while figures of 10.91 and 12.49 hours obtain for the two groups among the multiparous.<sup>19</sup>

TABLE 229  
HEIGHT AND BREADTH OF UTERUS IN THE PUERPERIUM  
(DeLee and Greenhill, 1947)<sup>7</sup>

<i>Time</i>	<i>Height</i>	<i>Breadth</i>
After delivery.....	10.91 cm.	11.05 cm.
1st day.....	13.55 cm.	12.27 cm.
2nd day.....	12.45 cm.	11.71 cm.
3rd day.....	11.16 cm.	10.93 cm.
4th day.....	10.21 cm.	10.27 cm.
5th day.....	9.29 cm.	9.66 cm.
6th day.....	8.22 cm.	8.96 cm.
7th day.....	7.61 cm.	8.32 cm.
8th day.....	7.32 cm.	8.19 cm.

THE PUERPERIUM. During the first week after delivery the uterus decreases in weight from about 1000 to 500 gm., and at the end of the second week it has decreased to approximately 375 gm. At the end of the puerperium (five to six weeks) it weighs 50 to 60 gm.<sup>22</sup>

## LACTATION

The amount of milk in the human varies with the demand. Ordinarily the yield is from 600 to 800 gm. a day, depending upon the needs of the nursing. Cases have been recorded where a wet nurse produced 2500 to 2800 gm. a day for a long period without injury.

TABLE 230  
CONSTITUENTS OF HUMAN MILK  
(Mattice, 1941)<sup>17</sup>

Protein, total.....	0.7-1.5 per cent
Casein.....	0.4 per cent
Albumin.....	0.8 per cent
Nonprotein nitrogen.....	0.02-0.03 per cent
Lactose.....	6-7.5 per cent
Fat.....	2-4 per cent
Cholesterol.....	0.01 per cent
Cephalin.....	0.037 per cent
Lecithin.....	0.078 per cent
Citric acid.....	0.05 per cent
Ash.....	0.15-0.30 per cent
Chlorides (as NaCl).....	120-500 mg./100 ml.
Calcium (as Ca).....	20-50 mg./100 ml.
Magnesium (as Mg).....	4-6 mg./100 ml.
Phosphorus (as P).....	15-25 mg./100 ml.
Sodium (as Na).....	10-15 mg./100 ml.
Potassium (as K).....	35-50 mg./100 ml.
Iron (as Fe).....	0.12-0.72 mg./100 ml.
Specific gravity.....	1.030-1.032
Water, per cent.....	87.4
Reaction (as pH).....	7-7.6

TABLE 230A  
COMPOSITION OF FETAL URINE  
(Makepeace et al., 1931)

<i>Constituents</i>	<i>I 9 Months</i>	<i>II 9 Months</i>	<i>III 6 Months</i>
Volume.....	30 ml.	5.5 ml.	25 ml.
Total N, mg./100 ml.....	41	43	61
Creatinine, mg./100 ml.....	..	..	4.6
Sugar, mg./100 ml.....	13	..	..
Cl as NaCl, mg./100 ml.....	136	362	171
Freezing-point depression.....	-0.141° C.	..	-0.174° C.

TABLE 230B  
COMPARATIVE DATA OF AMNIOTIC FLUID WITH OTHER BODY FLUIDS  
(Makepeace et al., 1931)

<i>Constituents</i>	<i>Normal Serum</i>	<i>Serum at Term</i>	<i>Spinal Fluid</i>	<i>Amniotic Fluid at Term</i>	<i>Amniotic Fluid at 3-4 Months</i>
Protein, mg./100 ml.....	7200	6100	29	233	266
N.P.N., mg./100 ml.....	27	24	18	27	27
Creatinine, mg. 100 ml. ....	1.35	1.55	1.77	2.30	1.43
Sugar, mg./100 ml.....	98	114	65	33	58
NaCl, mg./100 ml.....	592	604	726	622	640
Na, mg./100 ml.....	317	311	326	291	302
Ca, mg./100 ml.....	9.5	8.4	4.7	6.3	8.3
Water, per cent.....	91.04	91.68	98.90	98.79	98.74
Total solids, per cent.....	8.96	8.37	1.10	1.21	1.26
Freezing-point depression, -°C.....	0.571	0.551	0.570	0.502	0.542

TABLE 230C  
COMPARISON OF MATERNAL SERUM AND AMNIOTIC FLUID AT TERM  
(Makepeace et al., 1931)

<i>Constituents</i>	<i>Serum</i>			<i>Amniotic Fluid</i>		
	<i>Minimum</i>	<i>Maximum</i>	<i>Average</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Average</i>
Protein, mg. 100 ml.	5300	6800	6100	105	502	233
N.P.N., mg./100 ml.....	19	32	24	18	39	27
Creatinine, mg./100 ml.....	..	..	1.55	..	..	2.3
Sugar, mg./100 ml.....	73	153	114	11	62	33
Cl as NaCl, mg./100 ml..	481	645	604	559	667	622
Na, mg./100 ml.....	285	341	311	273	314	291
Ca, mg./100 ml.....	..	..	8.4	..	..	6.3
Total solids, per cent....	7.29	10.04	8.37	1.01	1.47	1.21
Specific gravity.....	1.0200	1.0273	1.0237	1.0062	1.0086	1.0073
Freezing-point depres- sion -°C.....	0.526	0.573	0.551	0.463	0.540	0.502

AMNIOTIC FLUID

Amniotic fluid is believed to originate as a dialysate in equilibrium with the maternal and fetal blood which becomes diluted with fetal urine as pregnancy advances. Makepeace and his co-workers<sup>25</sup> point out that in the early months of pregnancy the amniotic fluid is isotonic with maternal serum and is similar in composition to that of other protein-poor fluids in osmotic equilibrium

TABLE 230D  
COMPARISON OF MATERNAL SERUM AND AMNIOTIC FLUID BEFORE TERM  
(Makepeace et al., 1931)

<i>Constituents</i>	<i>Serum</i>			<i>Amniotic Fluid</i>		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Protein, mg./100 ml. . . . .	5200	6700	6000	100	1050	378
N.P.N., mg./100 ml. . . . .	17	34	25	18	36	26
Creatinine, mg./100 ml. . . . .	..	..	1.39	..	..	1.51
Sugar, mg. 100 ml. . . . .	88	142	118	11	86	42
Cl as NaCl, mg./100 ml. . . . .	584	638	604	605	725	648
Na, mg./100 ml. . . . .	300	313	309	296	309	302
Ca, mg./100 ml. . . . .	..	..	8.9	..	..	7.3
Total solids, per cent. . . . .	7.00	8.96	8.00	1.07	1.81	1.39
Specific gravity . . . . .	1.0210	1.0262	1.0239	1.0076	1.0121	1.0087
Freezing-point depres- sion - °C. . . . .	0.539	0.589	0.557	0.506	0.562	0.539

TABLE 230E  
COMPARISON OF MATERNAL SERUM AND AMNIOTIC FLUID IN 36 CASES  
(Cantarow et al., 1933)

<i>Constituents</i>	<i>Serum</i>			<i>Amniotic Fluid</i>		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Protein, mg./100 ml. . . . .	4070	7500	6060	0	1500	530
N.P.N., mg./100 ml. . . . .	13.76	36.00	23.98	13.6	37.5	24.25
Uric acid, mg./100 ml. . . . .	1.60	4.6	3.05	2.06	8.96	4.54
Sugar, mg./1000 ml. . . . .	48	108	84	0	59	19
Ca, mg./100 ml. . . . .	8.2	12.5	9.82	3.26	7.26	7.46
P, mg./100 ml. . . . .	3.5	5.7	4.3	1.2	5.4	3.1

with blood serum. At term the amniotic fluid becomes distinctly hypotonic. Since fetal urine is definitely hypotonic, the hypothesis has been advanced that as pregnancy progresses, the amniotic fluid becomes more and more diluted with hypotonic fetal urine. The composition of fetal urine in three cases studied by Makepeace and his co-workers<sup>26</sup> is given in Table 230a.

Amniotic fluid in the early months of pregnancy is clear and colorless; at term it is cloudy and of a pale straw color. The volume normally ranges from

500 to 1250 ml. According to Cantarow and his colleagues,<sup>26</sup> the most consistent difference between dialysates and amniotic fluid is the relatively high concentration of uric acid. In their analyses the uric acid concentration of amniotic fluid ranged from 2.1 to 9 mg. per 100 ml. (average, 4.54) and exceeded the uric acid concentration of maternal blood in thirty-one out of thirty-six cases.

Data pertaining to the composition of amniotic fluid are given in Tables 230b, c, d, and e.

THE FETUS

The length of the fetus is regarded as a good index of its age. The rule of Ahfelt and Haas, as outlined here, is useful in clinical work.

Ahfelt and Haas' Rule

Length at	1 lunar month	1 cm.
Length at	2 lunar months	4 cm.
Length at	3 lunar months	9 cm.
Length at	4 lunar months	16 cm.
Length at	5 lunar months	25 cm.
Length at	6 lunar months	30 cm.
Length at	7 lunar months	35 cm.
Length at	8 lunar months	40 cm.
Length at	9 lunar months	45 cm.
Length at	10 lunar months	50 cm.

For determinations of the age of the human fetus and its various measurements, see Tables 231 and 232.

TABLE 231  
RELATIONS OF AGE, SIZE AND WEIGHT IN THE HUMAN EMBRYO  
(Arey, 1946)<sup>3</sup>

Age of Embryo	Crown-Rump Length (mm.)	Crown-Heel Length (mm.)	Diameter of Chorionic Sac (mm.)	Weight in Grams
One week	0.1*	....	0.2	
Two weeks	0.2*	....	3	
Three weeks	2.0	....	10	
Four weeks	5.0	....	20	.02
Five weeks	8.0	....	25	
Six weeks	12.0	....	30	
Seven weeks	17.0	19.0	40	
Second lunar month	23.0	30.0	50	1
Third lunar month	56.0	73.0	....	14
Fourth lunar month	112.0	157.0	....	105
Fifth lunar month	160.0	239.0	....	310
Sixth lunar month	203.0	296.0	....	640
Seventh lunar month	242.0	355.0	....	1080
Eight lunar month	277.0	409.0	....	1670
Ninth lunar month	313.0	458.0	....	2400
Full term (266 days)	350.0	500.0	....	3300

\* Total length of embryonic disk.

TABLE 232

DETERMINATION OF THE AGE OF THE HUMAN FETUS  
(Friedenthal, 1914)<sup>12</sup>

<i>Age in Weeks</i>	<i>Weight in Grams</i>	<i>Length (mm.)</i>	<i>Hair System</i>	<i>Tooth System</i>	<i>Centers of Ossification</i>
1	0.03				
2	0.03-0.46				
3	0.46-1.8	0 15 1.5			
4	1 8 2 7	1 5 7 0			
5	2 7 4 0	7 0-10 7	.....	Epithelial thickening of upper and lower jaw	
6	4 0 22	10.7 14.9	Beginning of the hair anlage of the eyebrow	Dental furrow formed	
7	22 80	14.9 20	Eyebrow	.....	Radius, ulna, clavicle, tibia
8	80 160	20 25	.....	.....	Femur, ribs, humerus, scapula, hand phalanges, 3rd row
9	...	...	Beginning of the hair anlage of the trunk	.....	Fibula, metacarpals, frontal hand phalanges, 1st row
10	...	...	.....	Dental papilla anlage	Occipital, palatal of maxilla
11	160-550	80	Eruption of hair through the skin of head	.....	Ribs (except last), zygomatic, zygomatic process of temporal ilium, hand phalanges 2d row
12	...	...	.....	.....	Spine of scapula, nasal, toe phalanges, 3rd row
13	...	...	.....	.....	Metatarsals 1-5, bodies of cervical vertebrae
14	550 820	130	.....	.....	Vertebrae, 3 centers, last rib, toe phalanges, 1st row, annulus tympanicus
15	...	...	.....	.....	Manubrium sternum
16	820-1120	230	Beginning formation of hairy head cap	Enamel germ of the permanent teeth	Scapula, ischii
17	1120-2200				Pubis, calcaneus, talus
18					Toe phalanges, 2d row
19				Dentin cone of the milk teeth	

TABLE 232—Continued

Age in Weeks	Weight in Grams	Length (mm.)	Hair System	Tooth System	Centers of Ossification
27.....	2200-2850	370	Beginning of hair rudiment of hand and back of foot		
30.....	2850-3350	420			
34.....	3350-3900	468			
37.....	3900-4500	508-550	Decline of lanugo hair on body and face	....	Sternum—7 centers
38.....				Dental sac for 1st molar	Distal epiphysis of femur Proximal epiphysis of tibia, cuboid, toe phalanges

WEIGHT. The average weight at birth is 7 pounds (3200 gm.). Male infants average 3 ounces (100 gm.) heavier than girls. Infants weighing more than 10 pounds (4500 gm.) are excessive in size. However, infants are occasionally reported to weigh more than 5000 gm. at birth. (See also Anatomical Normals, Chapter 64.)

BLOOD. The blood of the newborn shows a variation from that of the normal adult. The erythrocyte count is 5 to 6.5 million red cells. The leukocyte count is 15 to 20 thousand white cells. The cell volume is 45 to 50 per cent, and the hemoglobin is 20 to 22 gm. (See also Chapter 6.)

CIRCULATION. Figure 115 shows the circulation of the fetus in utero and also of the newborn.

FOOD AND NUTRITIONAL REQUIREMENTS DURING PREGNANCY

The Committee on Food and Nutrition has determined the essential daily food requirements. Table 383 (p. 716) gives their recommendations for women during the later period of pregnancy and lactation.

PELVIC TYPES

A knowledge of the standard pelvic types seen in pregnancy is essential for prognosis of delivery. Caldwell, Moloy and D'Esopo<sup>5</sup> have classified the pelvis according to its configuration.

The *gynecoid* pelvis is the type most commonly found and is the correct type adaptable to pregnancy and delivery. The shape of the inlet is such that passage of the presenting part will be facilitated by the general roundness of the area with deep fore and posterior segments. The bones are lighter and the pelvic cone is shallow.

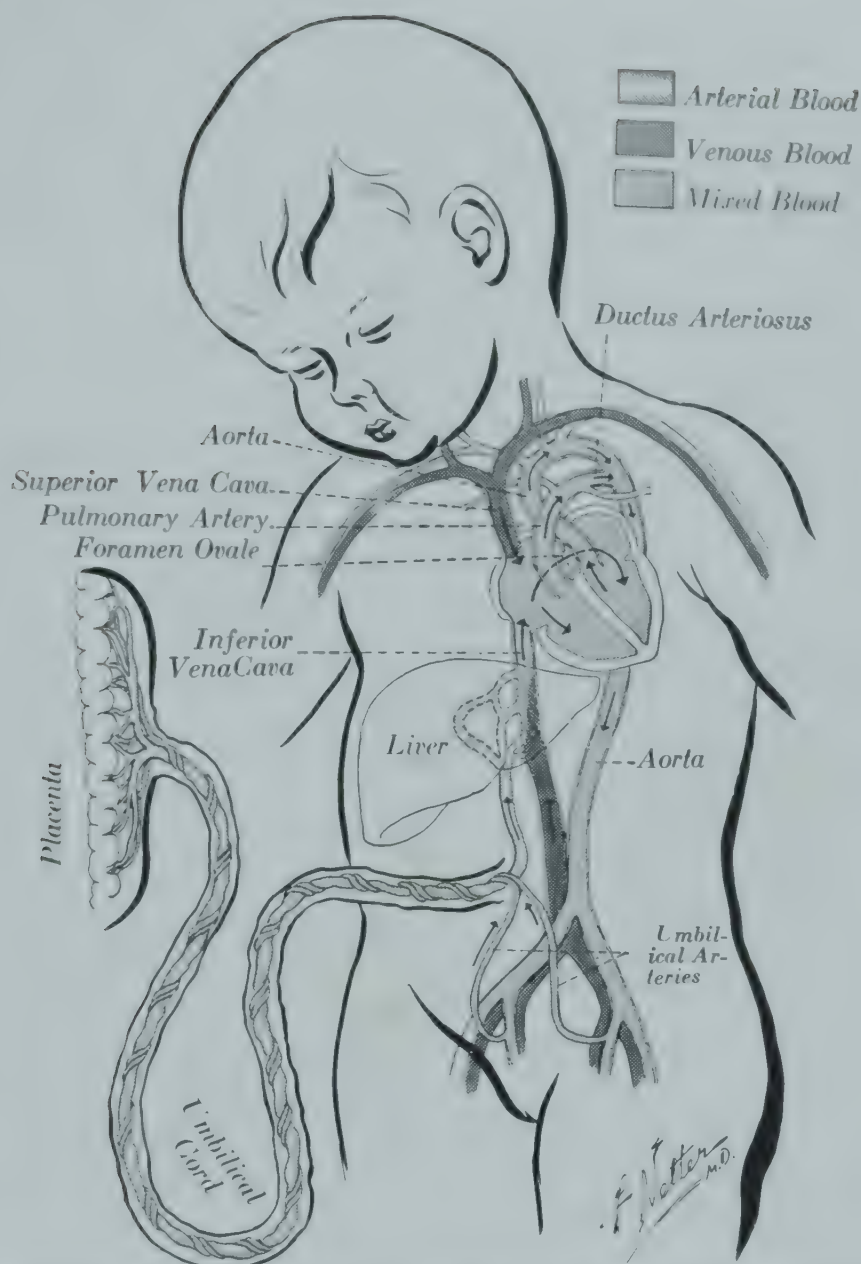


Fig. 115. Diagram of fetal circulation. (Bookmiller and Bowen: Obstetrics and Obstetric Nursing.)



Fig. 116. Side view of fetal skull. Biparietal diameter—B.P., 9½ cm. Bitemporal diameter—B.T., 8 cm. Suboccipitobregmatic diameter—S.O.B., 9½ cm. Occipitofrontal diameter—O.F., 11 cm. Occipitomentale diameter—O.M., 13 cm. DeLee and Greenhill: Principles and Practice of Obstetrics.

The *android* or *male* pelvis is not suited for pregnancy and delivery because of the heavy bone segments, shallow posterior segments, the heart shape and general tendency to funneling because of the prominent ischial spines.

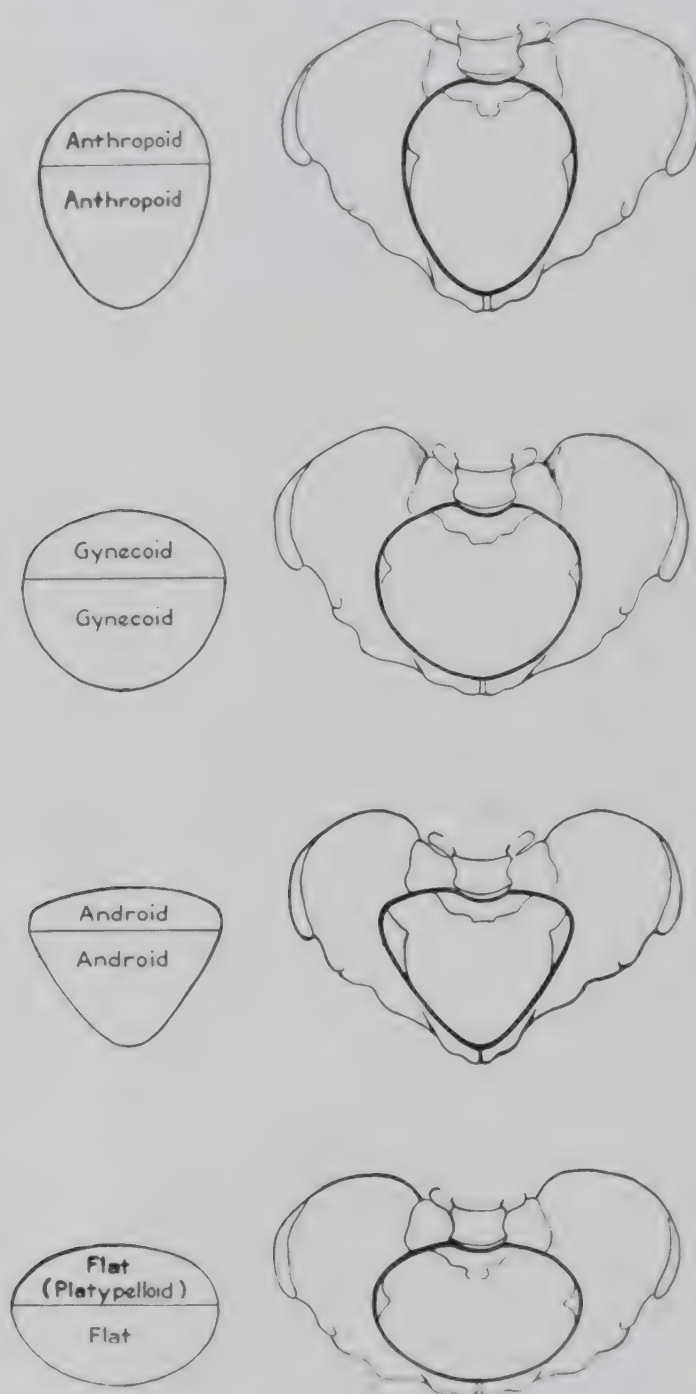


Fig. 117. Pure types of pelvic inlet. Caldwell, W. E., Moloy, H. C., and D'Esopo, D. A.: *Am. J. Obst. & Gynec.*, vol. 40.)

The *flat* or *platypelloid* pelvis, seen in the rachitic patient, is also a poor type because of the narrowing of the anteroposterior diameter and wide transverse diameter. Both anterior and posterior segments are shallow. The transverse position is favored in this pelvis. Relative and absolute disproportions are most likely in this type. It is therefore not suited to vaginal delivery.

The *ape* or *anthropoid* pelvis is the opposite of the platypelloid in that the anteroposterior diameter is the longest and the transverse diameter is narrowed.

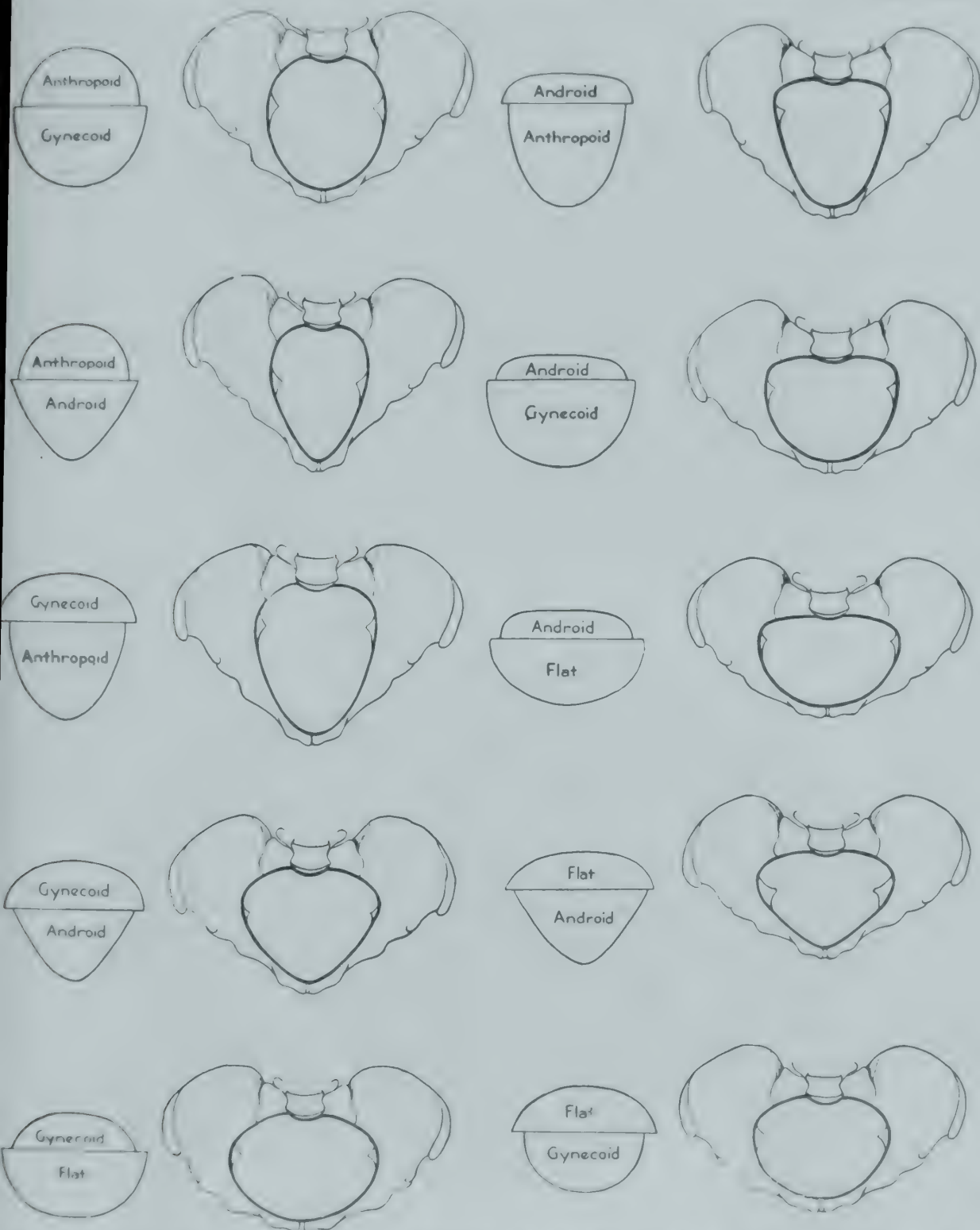


Fig. 118. Mixed types of pelvic inlet. Caldwell, W. E., Moloy, H. C., and D'Esopo, D. A.: Am. J. Obst. & Gynec., vol. 40.)

It has a deep posterior segment and tends to favor the posterior position of the occiput. This pelvis also tends to general funneling with narrowing of the outlet with dystocia at this point.

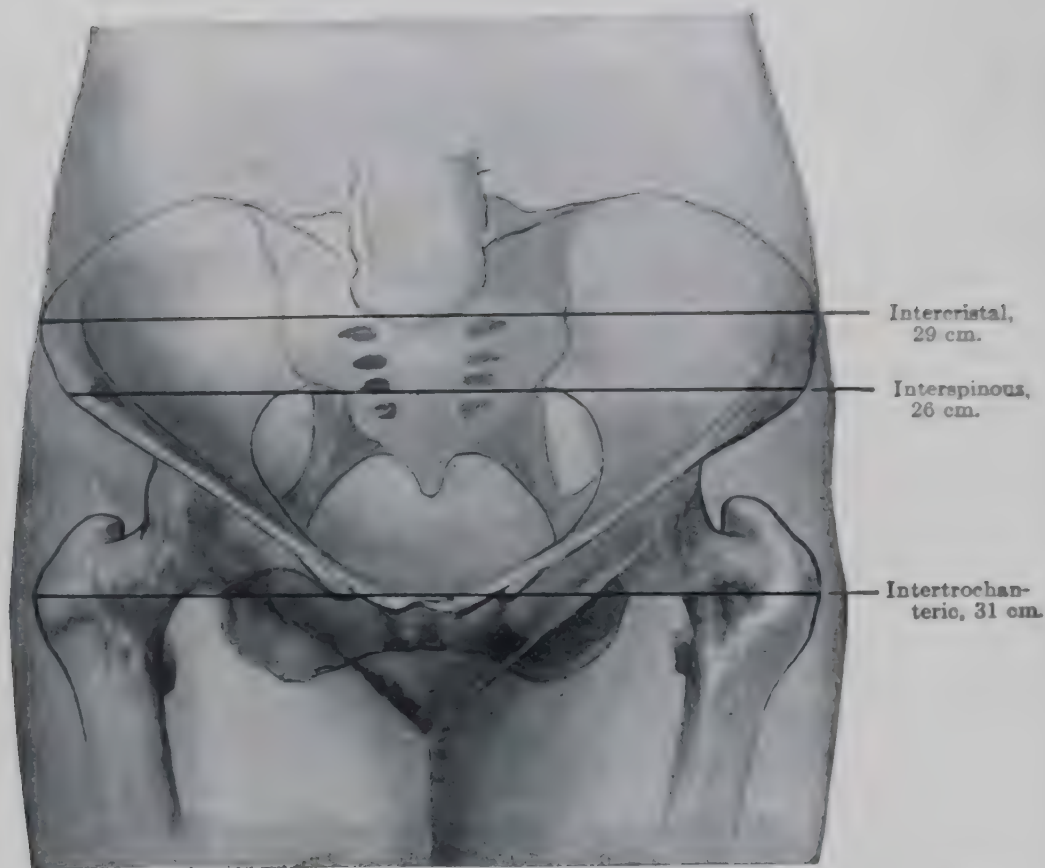


Fig. 119. External measurements, showing where to place the pelvimeter.  
(DeLee and Greenhill: Principles and Practice of Obstetrics.)

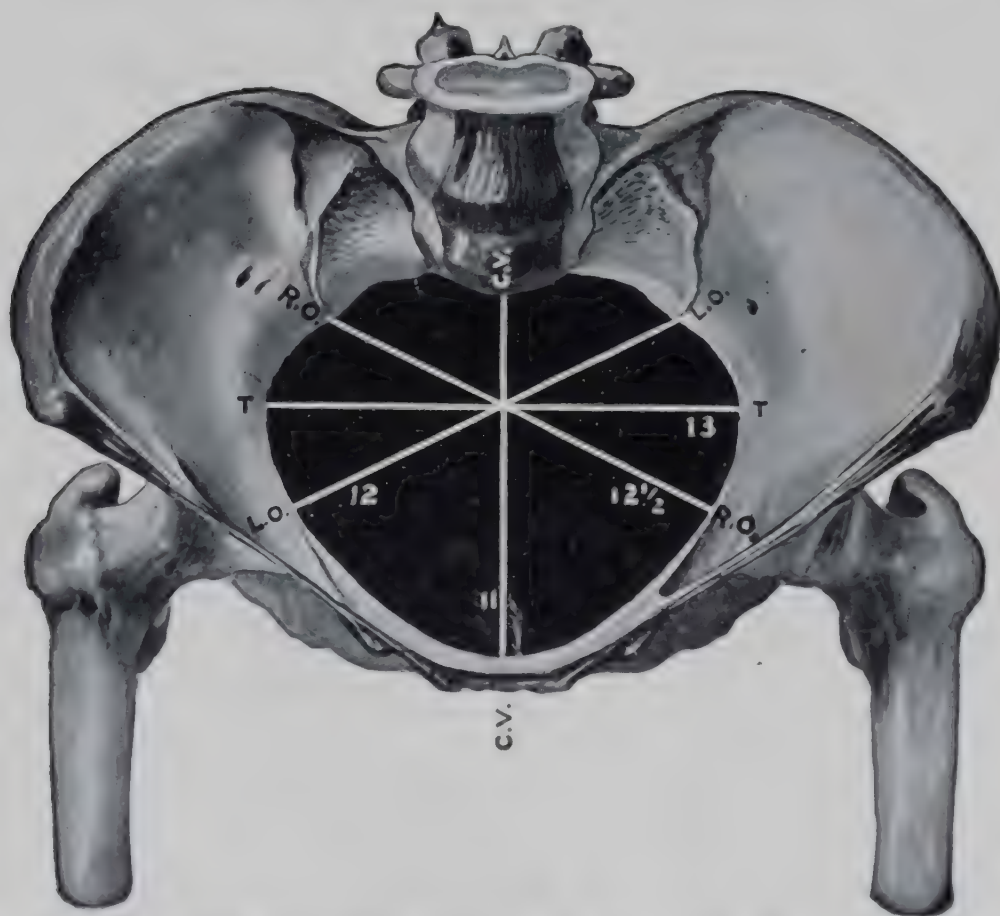


Fig. 120. Pelvic inlet with diameters. (DeLee and Greenhill: Principles and Practice of Obstetrics.)

The double combination of any of these pelvis types may be seen. Pelvic deformity due to disease can hardly be considered normal and will not be mentioned.

The frequency of these pure types of pelvis among white women is:

Gynecoid type.....	41.4 per cent
Android type.....	32.5 per cent
Anthropid type.....	23.5 per cent
Platypelloid type.....	2.6 per cent

## PELVIMETRY

(Pelvic Mensuration)

A knowledge of the size and shape of the parturient passages may be obtained by measuring the pelvis. Both external and internal measurements are

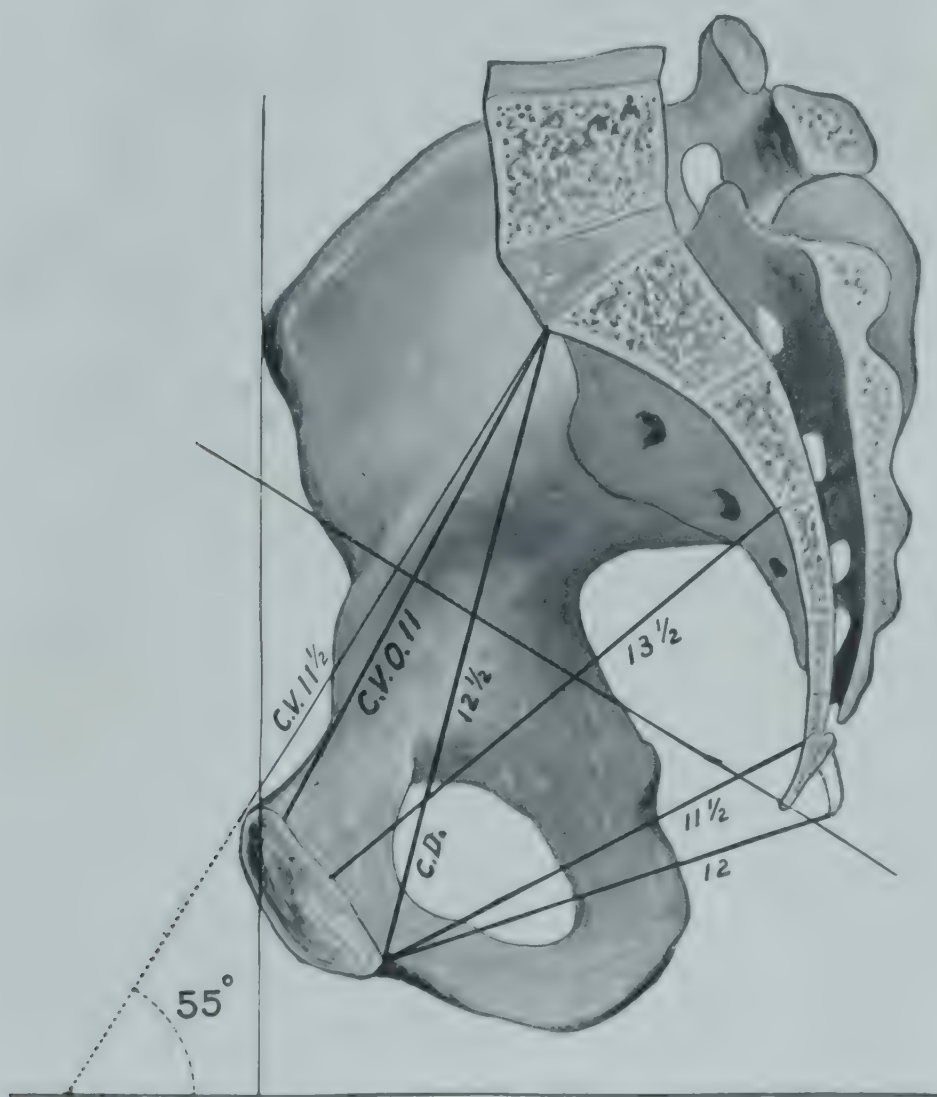


Fig. 121. Sagittal section of pelvis, showing diameters (Hodge). C.V., Anatomic conjugate; C.V.O., obstetric conjugate; C.D., diagonal conjugate. The pelvic inclination is shown as 55 degrees, but Jacobs claims it is 48 degrees.

made. The external measurements are usually taken first. Figures 119, 120, 121 and 122 illustrate the measurements and methods for obtaining them.

## THE PLACENTA

The size of the placenta at birth varies in relation to the size of the child. The average weight is 500 to 600 gm. The average measurements are 18 by 16 by 2.5 cm.



Fig. 122. Thoms' method of measuring the inlet with the centimeter grid. Courtesy of Dr. Thoms.) (DeLee and Greenhill: Principles and Practice of Obstetrics.)

The rate of growth of the placenta during pregnancy averages 60 gm. a month until the seventh month, then 50 gm. a month until the ninth month, and only 10 gm. are added during the tenth month.

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Section X

SKELETON AND SKELETAL MUSCLES

(Normal Values in Orthopedics)



## Chapter 49

### SKELETON AND SKELETAL MUSCLES

THE NORMAL skeleton is composed of 206 bones (see Table 233). In considering what constitutes the normal growth, development and function of the skeletal system and its associated structures, it is recognized that people differ one from another to a marked degree, and the problem is to indicate the range of varia-

TABLE 233  
NUMBER OF BONES IN ADULTS  
(Gray, 1942)<sup>8</sup>

Axial skeleton.....	{	Vetebral column.....	26	
		Skull.....	22	
		Hyoid bone.....	1	
		Ribs and sternum.....	25	74
Appendicular skeleton {	{	Upper extremities.....	64	
		Lower extremities.....	62	126
Auditory ossicles.....				6
Total.....				206

tion to be considered normal. A certain amount of deflection from the average is not associated with abnormal function, may be regarded as within normal limits.

#### NORMAL BONE

Bone is well adapted by its strength and lightness for its function as a supporting framework for the body. It is a living tissue and as such is always undergoing the processes of tissue destruction and repair, and is continually being remodeled by the demands the body makes upon it.

An appreciation of the normal appearance of bone as a tissue and its anatomic variations can best be obtained by roentgenographic study. In the extremities there are two types of bones: the elongated tubular bones in the arms, hands, legs and feet, and the round bones in the wrist and ankles. The small, rounded sesamoid bones are situated in the tendons and articular capsules. The patellas are the largest of the sesamoids. The tubular bones are all basically similar in structure and growth, although they vary in size and shape. A growing tubular bone consists of a shaft or diaphysis capped at each end by a mass of cartilage, the epiphysis, in which the secondary ossification center develops.

**OSSIFICATION CENTERS.** Ossification, first seen in the cartilaginous skeleton about five fetal months, continues in various parts of the skeleton at intervals up to about the twenty-second year. The order and date of the ossification

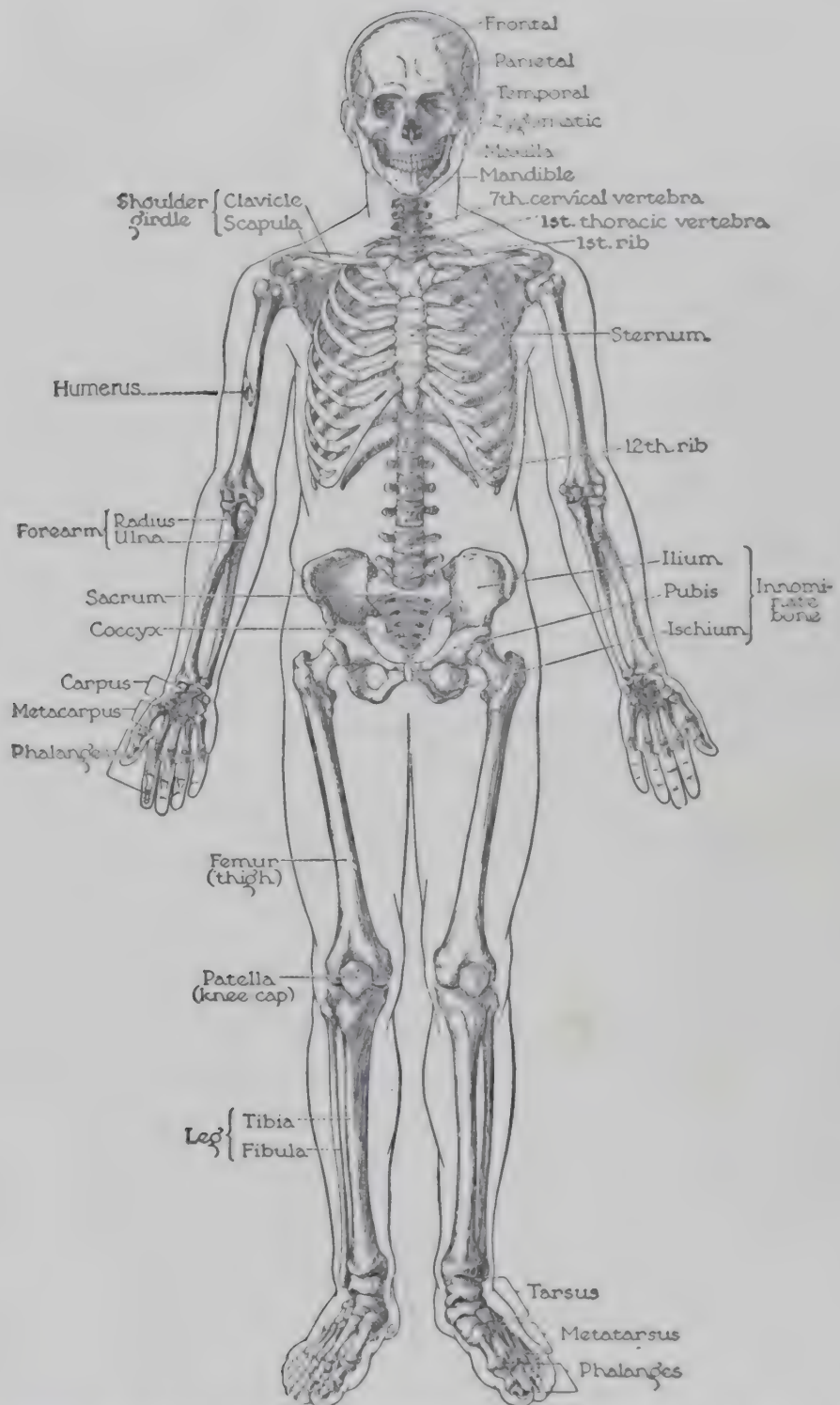


Fig. 123. Anterior view of the human skeleton. (Millard and King: Human Anatomy and Physiology.)

centers is the first and earliest method of estimated normal skeletal development. Figures 125, 126, 127, 128 and 129 give time schedules for the appearance of ossification centers.

**EPIPHYSIS.** The epiphysis is a structure specialized for growing and forming the articular end of a bone. It is entirely cartilaginous at first, but as it ossifies

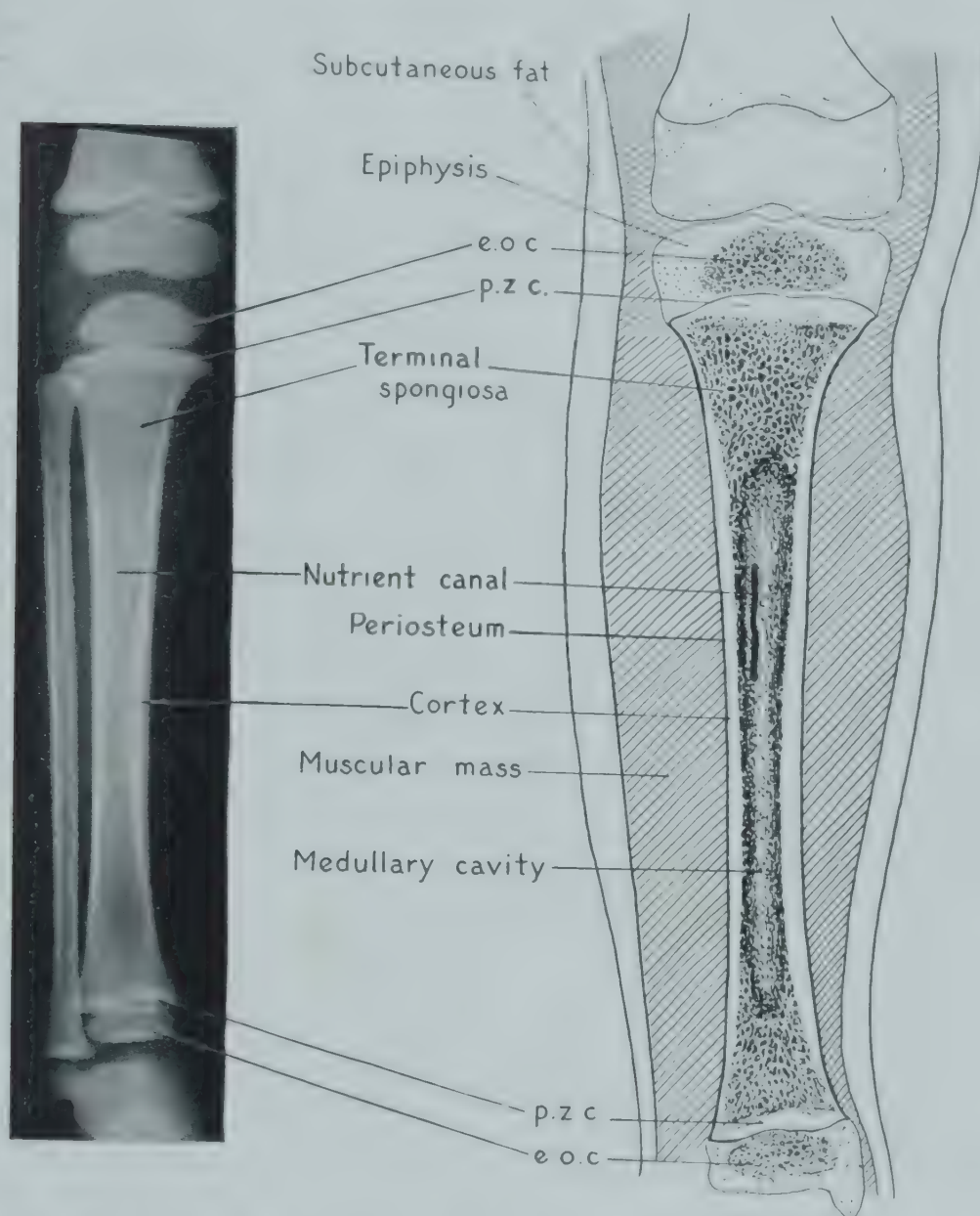


Fig. 124. The macroscopic components of a normal tubular bone and their roentgenographic counterparts. A, Roentgenogram; B, longitudinal section of the right tibia of a child 5 years of age; e.o.c., epiphyseal ossification center; p.z.c., provisional zone of calcification. (Adapted from Caffey, J.: *Pediatric X-Ray Diagnosis*, The Year Book Publishers, Inc.)

centrally, its bony structure remains demarcated from the remainder of the bone by a thin line of cartilage. Elongation and ossification of a tubular bone occur as the cells in the proliferative cartilage multiply continually and are driven off away from the cartilage toward the shaft. The addition of these new

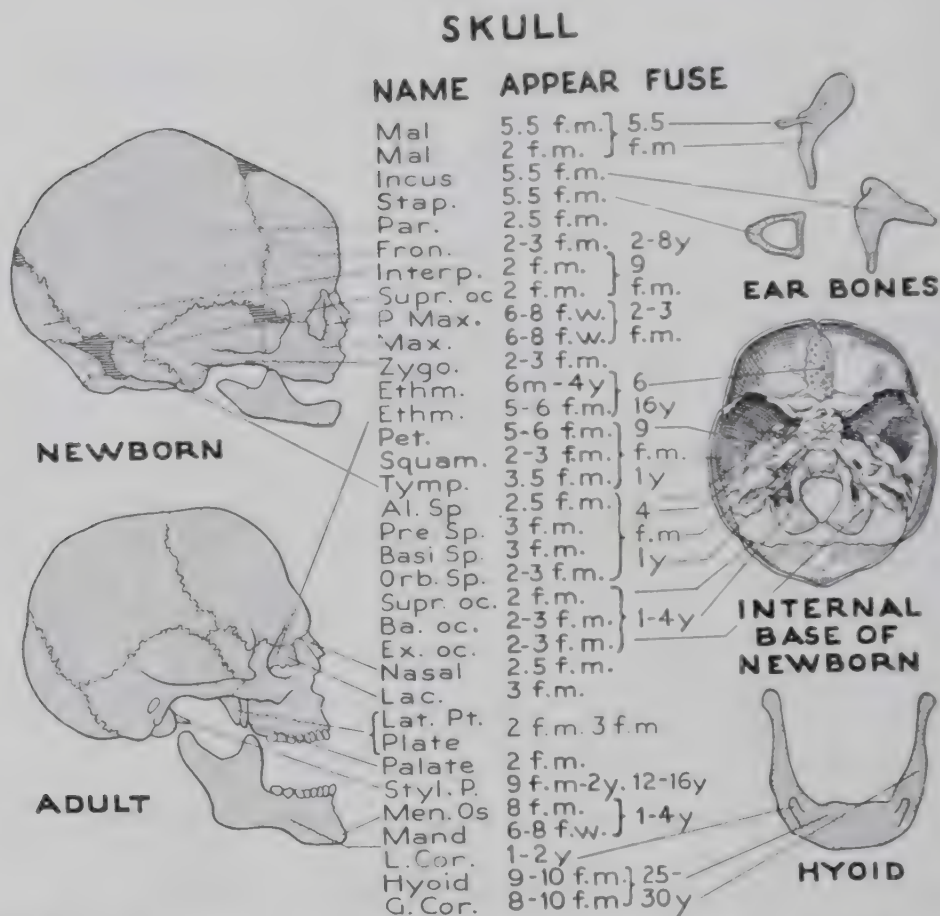


Fig. 125. Fetal and postnatal ossification of the skull, showing the time of appearance and of fusion of the different ossification centers: *f.m.*, fetal month; *f.w.*, fetal week; *y*, year. Reprinted from Scammon in Morris' Human Anatomy. (From Caffey, J.: Pediatric X-Ray Diagnosis, Year Book Publishers, Inc.)

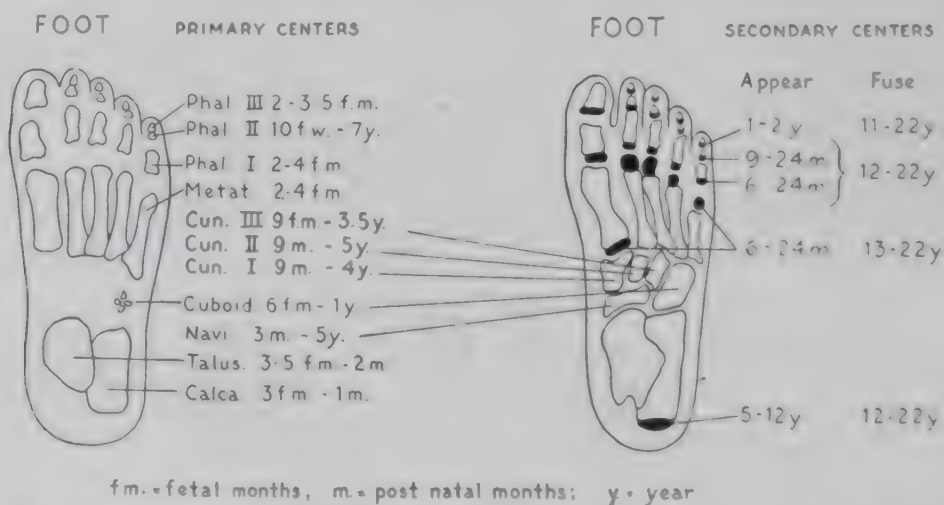
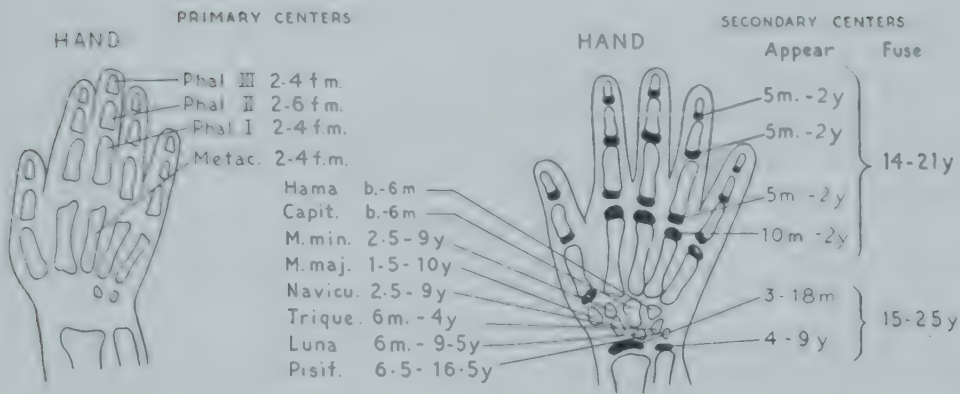


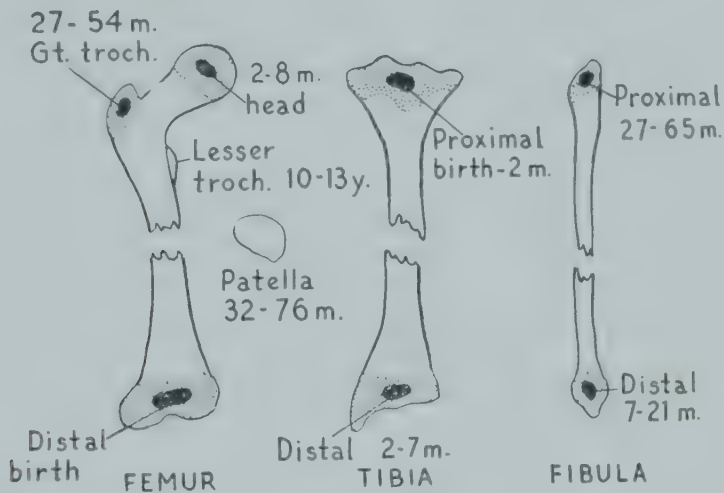
Fig. 126. Time schedule for appearance of primary and secondary ossification centers and fusion of secondary centers with the shafts in the feet. Modified from Scammon in Morris' Human Anatomy. (From Caffey, J.: Pediatric X-Ray Diagnosis, Year Book Publishers, Inc.)



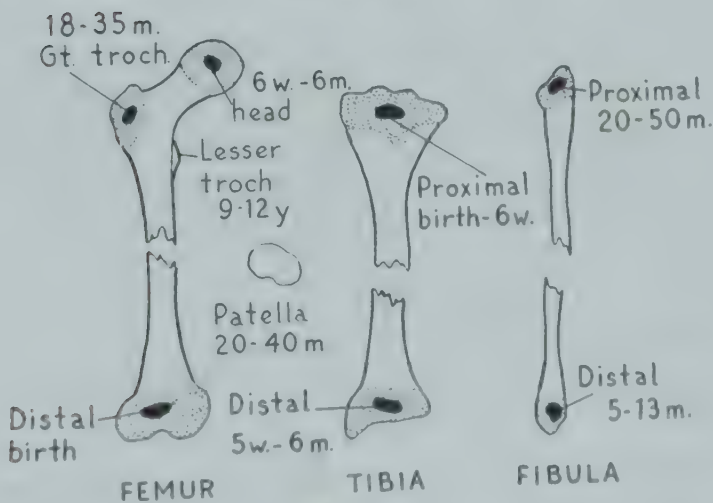
f.m. = fetal months, b. = birth, m. = post natal months; y = year

Fig. 127. Time schedule for appearance of primary and secondary ossification centers and fusion of secondary centers with the shafts in the hands. (Modified from Scammon in Morris Human Anatomy. (From Caffey, J.: Pediatric X-Ray Diagnosis, Year Book Publishers, Inc.)

### BOYS



### GIRLS

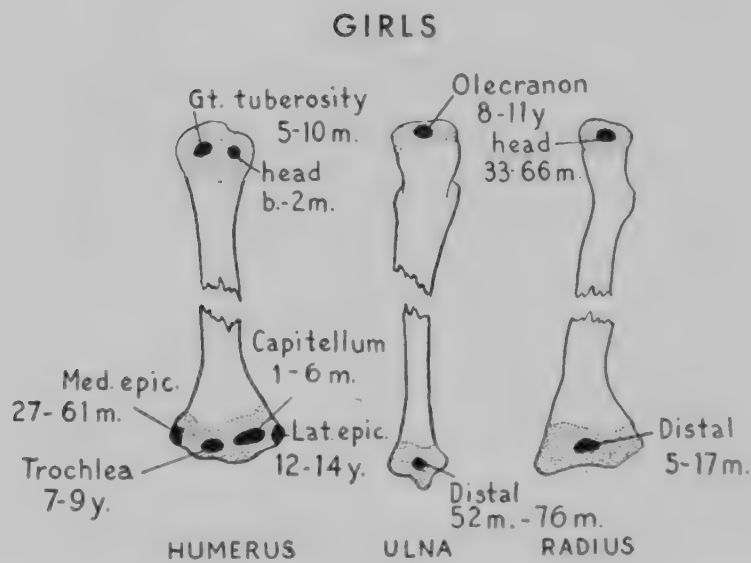
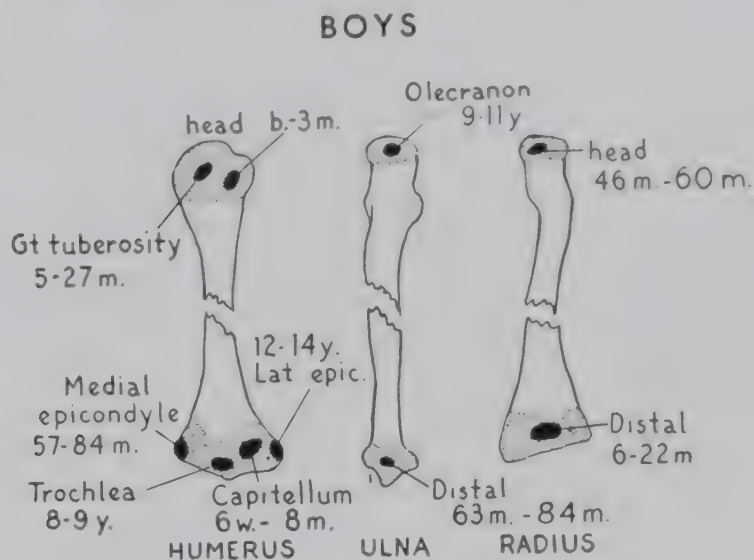


w. = weeks; m. = months

Fig. 128. Time schedule for appearance of secondary epiphyseal ossification centers in the lower extremity. (Modified from Vogt and Vickers. (From Caffey, J.: Pediatric X-Ray Diagnosis, Year Book Publishers, Inc.)

cells lifts the cartilage away from the shaft and increases its length. Girls' bones elongate more rapidly than those of boys.

The epiphyseal cartilage ultimately disappears, and the resulting bone nodule fuses with the main mass of the bone. In a general way the epiphyses



m. = months y. = years b. = birth.

Fig. 129. Time schedule for appearance of secondary epiphyseal ossification centers in the upper extremity. (Modified from Vogt and Vickers.) (From Caffey, J.: *Pediatric X-Ray Diagnosis*, Year Book Publishers, Inc.)

which ossify early unite with the shafts late. Just as the order and date of the appearance of ossification centers is the first and earliest method of estimating normal skeletal development, so the union of the epiphyses is another significant indicator of developmental progress. A deviation of more than nine months from the mean date of union is evidence of real acceleration or retardation.

The ranges in Table 234 express the mean date with twice the standard deviation on each side of the mean. The dates refer to completion of union. It is rather common to find girls a year accelerated and boys retarded two or three years. The normal maturation of the bones of the hands is shown in Figure 130 and of the feet in Figure 131.

### NORMAL VARIATIONS IN STRUCTURE AND DEVELOPMENT

There are many normal variations in structure and development in the epiphyses, small bones and occasional bones (see Figures 132, 133 and 134).

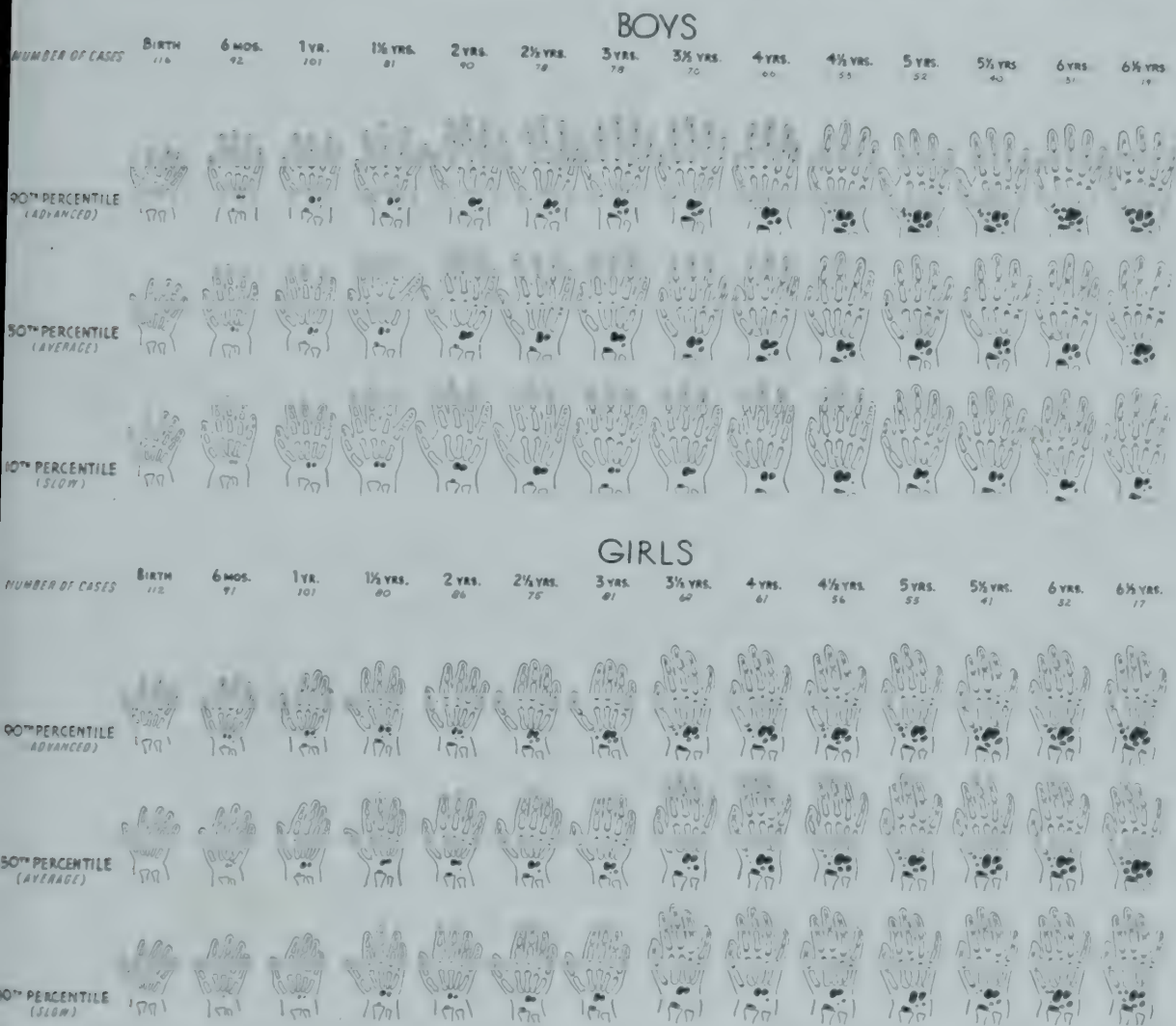


Fig. 130. Normal maturation of the bones of the hands in boys and girls. (Vogt, E. C., and Vickers, V. S.: Radiology, vol. 31.)

**HAND.** The middle phalanx of the fifth digit varies considerably in size. Hypoplasia is found in 1 per cent of normal children. In the second metacarpal, supernumerary ossification centers may develop in the proximal epiphyses. Two ossification centers may appear in the cartilage of the navicular.

**FOREARM.** During the first months of life the distal end of the shaft of the ulna and occasionally the radius may be cupped physiologically.

**ELBOW.** The trochlear epiphyseal center is usually irregularly mineralized

and always develops from several small foci. Occasionally a sesamoid bone is seen in the triceps tendon, called the patella cubiti. In the distal end of the humerus the bony septum which separates the olecranon fossa behind from the coronoid fossa in front is occasionally perforated and a supratrochlear foramen is present.

**FEET.** The middle and terminal phalanges of the fifth toe are often fused. In most children the epiphyses for the middle phalanx of the third and fourth

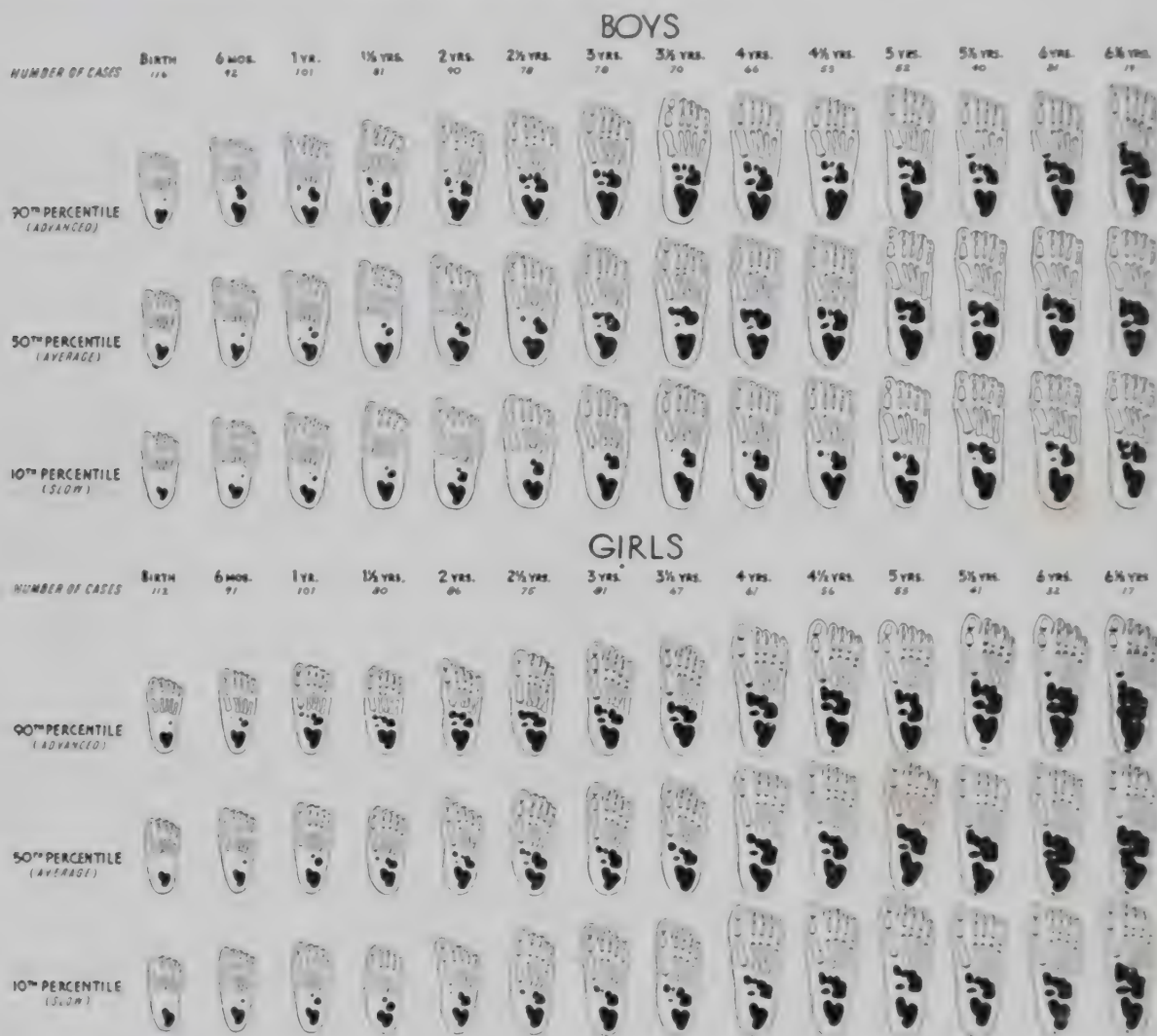


Fig. 131. Normal maturation of the bones of the feet. (Vogt, E. C., and Vickers, V. S.: Radiology, vol. 31.)

toes do not have separate ossification centers. Bipartite sesamoids are common. An accessory ossification center may develop in the distal end of the first metatarsal.

**TARSAL BONES.** There is an inconstant accessory ossicle in the medial process of the navicular, the os tibiale externum. In the astragalus there is a common accessory bone in the tip of the posterior process, the os trigonum. The apophyseal center of the calcaneus appears between the sixth and tenth years. Other supernumerary ossicles are the os peroneum at the plantar angle

of the cuboid bone, Pierie's bone at the dorsal aspect of the head of the talus, the os intermetatarsium between the second metatarsal and the base of the first metatarsal, and the os vesalianum at the base of the fifth metatarsal (see also Figure 132).

TIBIA. In many children the tip of the distal epiphysis (the internal malleolus) shows a separate ossicle. Figure 133 shows variations in the size and configuration of the anterior tibial process.

TABLE 234  
AGE ORDER OF EPIPHYSEAL UNION IN MAN  
(From T. W. Todd, 1930)<sup>6</sup>

Skeletal Site	Usual Limits of Union in Years and Months*	
	Male	Female
Pelvis . . . . .	14.0-14.11	12.6-13.5
Distal humerus . . . . .	14.0-14.11	12.6-13.5
Foot, 3rd phalanx . . . . .	14.6-14.11	12.6-13.5
Proximal ulna . . . . .	14.6-15.5	12.6-13.5
Calcaneus . . . . .	14.6-15.5	13.0-13.11
Foot:		
2d phalanx . . . . .	14.6-14.11	13.0-13.11
1st phalanx . . . . .	15.0-15.5	13.0-13.11
Metatarsals . . . . .	15.0-15.11	14.0-14.11
Hand:		
3rd phalanx . . . . .	15.0-15.5	13.0-13.11
1st phalanx . . . . .	15.6-15.11	14.0-14.11
2d phalanx . . . . .	15.6-15.11	14.0-14.11
Metacarpals . . . . .	15.6-16.5	15.0-15.11
Proximal radius . . . . .	15.0-15.11	12.6-13.5
Median epiphyseal humerus . . . . .	15.6-15.11	13.6-14.5
Distal fibula . . . . .	15.6-16.5	14.6-15.5
Distal tibia . . . . .	15.6-16.5	14.6-15.5
Femur, head . . . . .	17.0-17.11	17.0-17.11
Greater trochanter . . . . .	17.0-17.11	17.0-17.11
Proximal tibia . . . . .	17.6-18.5	17.6-18.5
Proximal fibula . . . . .	17.6-18.5	17.6-18.5
Distal ulna . . . . .	18.0-18.11	18.0-18.11
Distal femur . . . . .	18.0-18.11	17.6-18.5
Proximal humerus . . . . .	19.6-20.5	19.0-20.0

\* Left of decimal = number of months; right of decimal = number of years.  
Twice the standard deviation.

FIBULA. This is an inconstant sesamoid bone in the lateral head of the gastrocnemius.

PATELLA. Ossification develops from several small foci. The healthy patella is often granular, and the edges may be irregular.

**FEMUR.** The ossification center in the distal epiphysis increases in size and rapidly extends laterally from the second to the sixth year. During this time

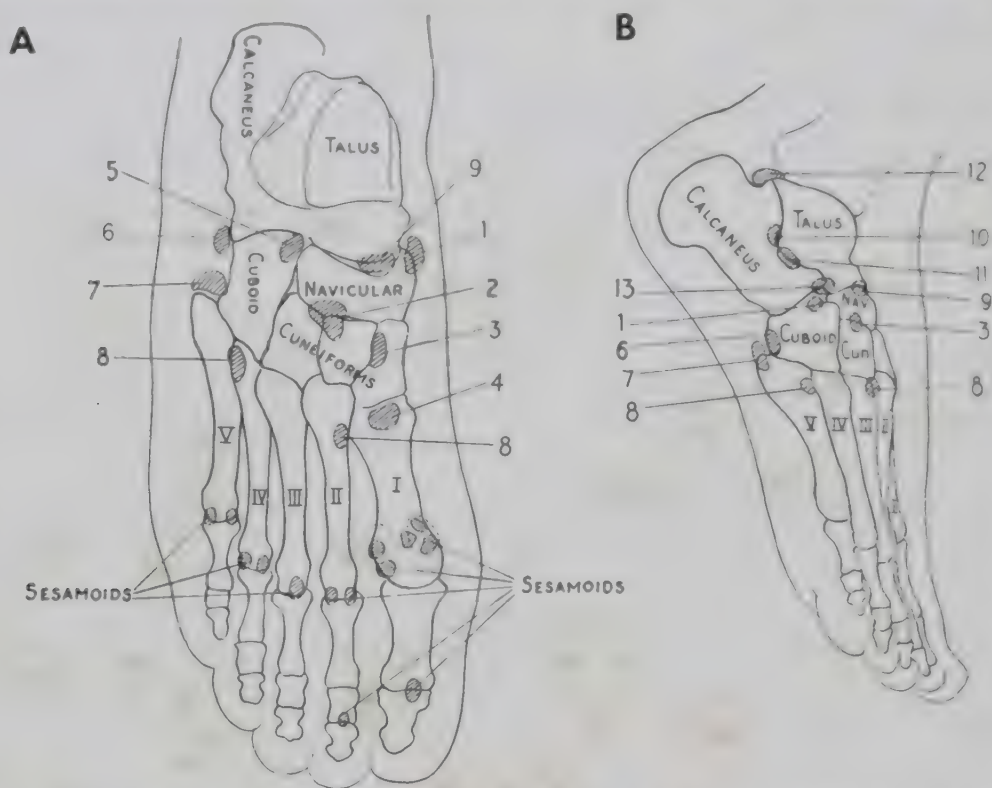


Fig. 132. Normal supernumerary ossicles of the feet. *A*, Ventrodorsal, and *B*, lateral projection. 1, Os tibiae externum; 2, processus uncinatus; 3, os intercuneiforme; 4, pars peronea metatarsalia I; 5, cuboides secundarium; 6, os peroneum; 7, os vesalianum; 8, os intermetatarsium; 9, accessory navicular; 10, talus accessories; 11, os sustentaculum; 12, os trigonum; 13, calcaneus secundarium. (Caffey, J.: *Pediatric X-Ray Diagnosis*, Year Book Publishers, Inc.)

the lateral and medial margins are commonly irregular and ragged. This appearance is also seen in the proximal tibial epiphysis.

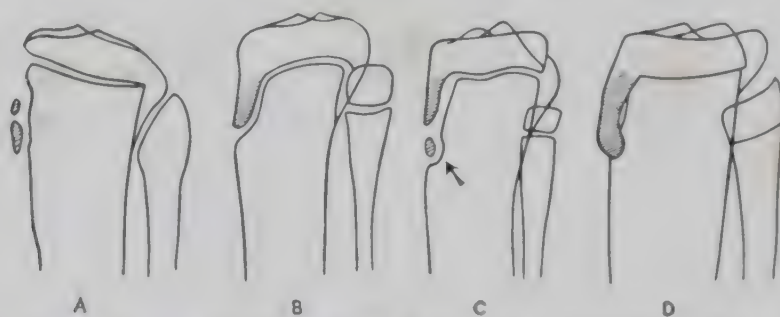


Fig. 133. Normal variations in the size and configuration of the anterior tibial process. (Modified from Koehler. Caffey, J.: *Pediatric X-Ray Diagnosis*, Year Book Publishers, Inc.)

## THE JOINTS

A joint is formed by the appearance of a fissure in the cartilaginous mass of the skeleton. The fissure may stop short of completion, and thus various forms of congenital fusion occur in which the function of the joint may or may

be impaired. Examples of this variation are widespread in the body, one of the commonest being the sacralization of the last lumbar vertebra.

Completely formed, a joint serves the function of separating bones from each other, at the same time holding them in contact by ligaments which are in turn protected by the muscles. The amount of motion in a joint depends on the shape of the joint surfaces, which vary in every type of person;

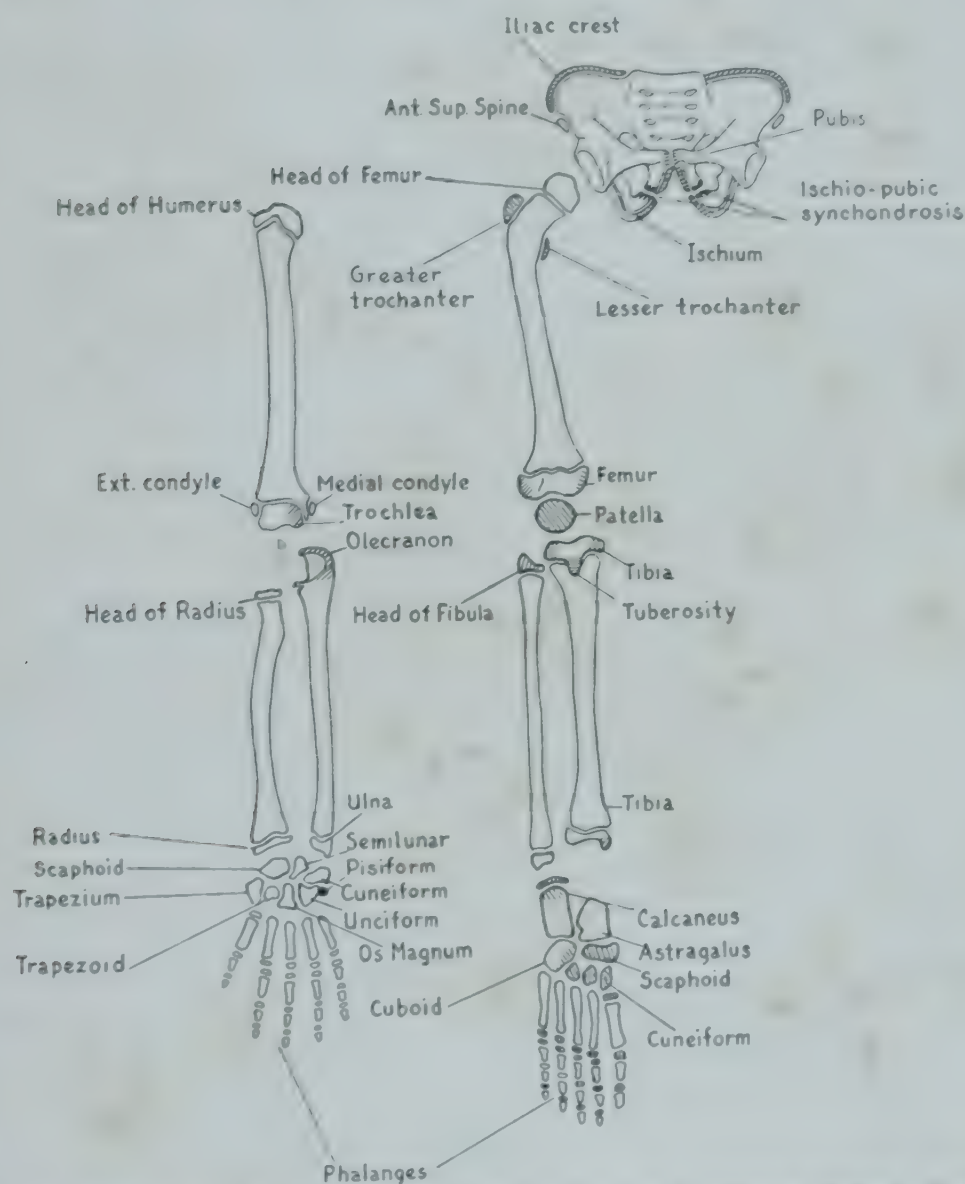


Fig. 134. Sites of normal irregular mineralization in the growing skeleton. Sites of physiologic irregular mineralization are shaded. (Caffey, J.: *Pediatric X-Ray Diagnosis*, Year Book Publishers, Inc.)

second, on the laxity or tightness of the ligaments; and third, on the condition of the protective muscles. There is in every joint a normal range of motion the limitations of which are an important index of joint disability. All motions are measured by degrees from a neutral point, which should be defined.

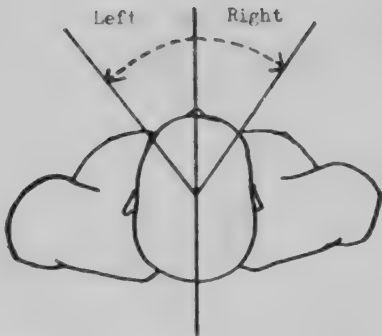
The normal ranges of motions of the various parts of the body are given and illustrated in Figures 135 to 147, inclusive.

TABLE 235  
NORMAL RANGES FOR MOTION  
*Cervical Spine*  
(Neutral position is the erect position)

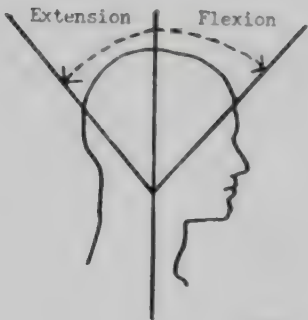
Flexion . . . . .	65°
Extension . . . . .	50°
Lateral bending . . . . .	40°
Rotation . . . . .	55°



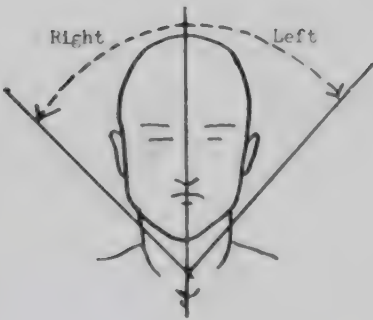
Neutral



1  
Rotation



2+3  
Flexion  
and  
Extension



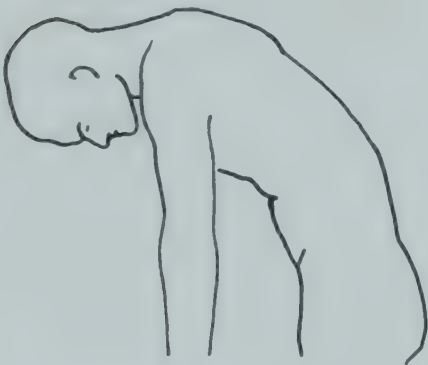
4  
Lateral Bending

Fig. 135. Normal motion of neck. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., v 4, 1922.)

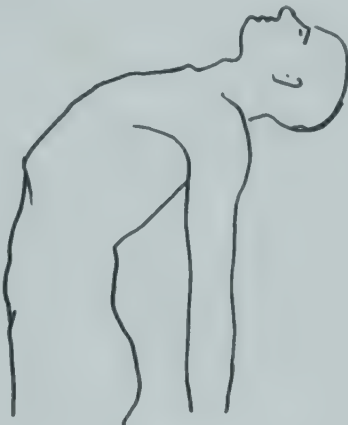
*Lumbar Spine*

(Neutral position is the erect position)

Flexion.....	95°
Extension.....	35°
Lateral bending.....	40°
Rotation.....	35°



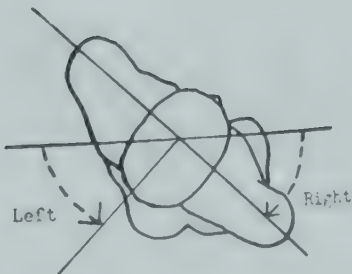
1  
Forward Bending



2  
Extension



3  
Lateral Bending



4  
Rotation

Fig. 136. Normal motion of the spine. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.)

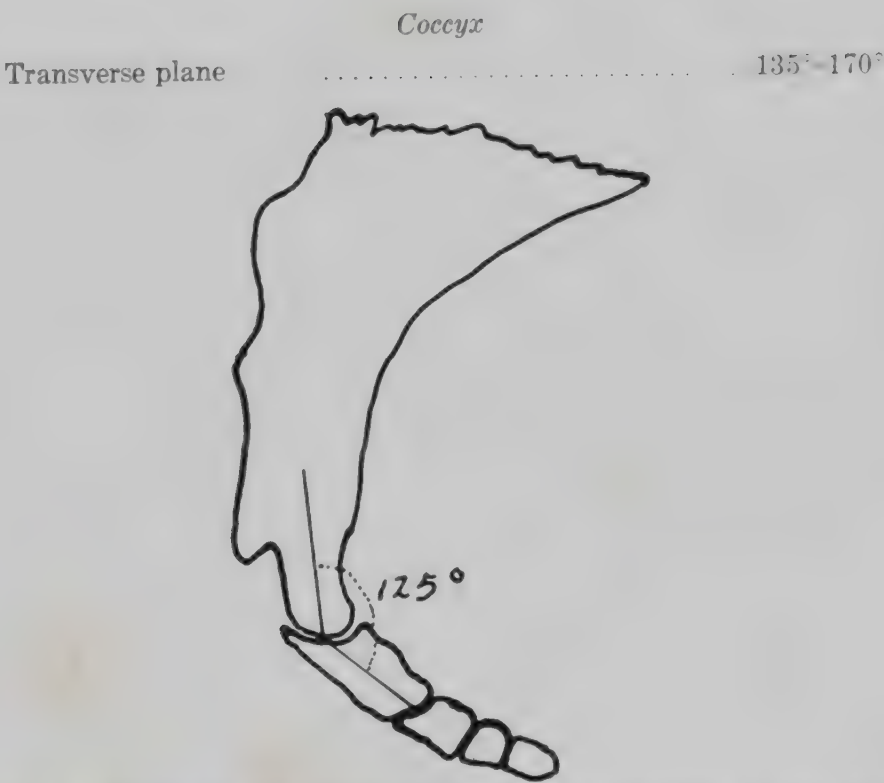


Fig. 137. Method of measuring the degree of angulation of the coccyx in relation to the sacrum, in the sagittal view. (Friedman, L. J., and Stein, C.: Radiology, vol. 31.)

Shoulder

Neutral position is arm-to-side, elbow flexed to 90°, forearm pointing forward

Abduction.....	100°-110°
Adduction.....	20°- 40°
Flexion.....	80°-100°
Extension.....	20°- 45°
Internal rotation.....	80°-100°
External rotation.....	80°- 95°

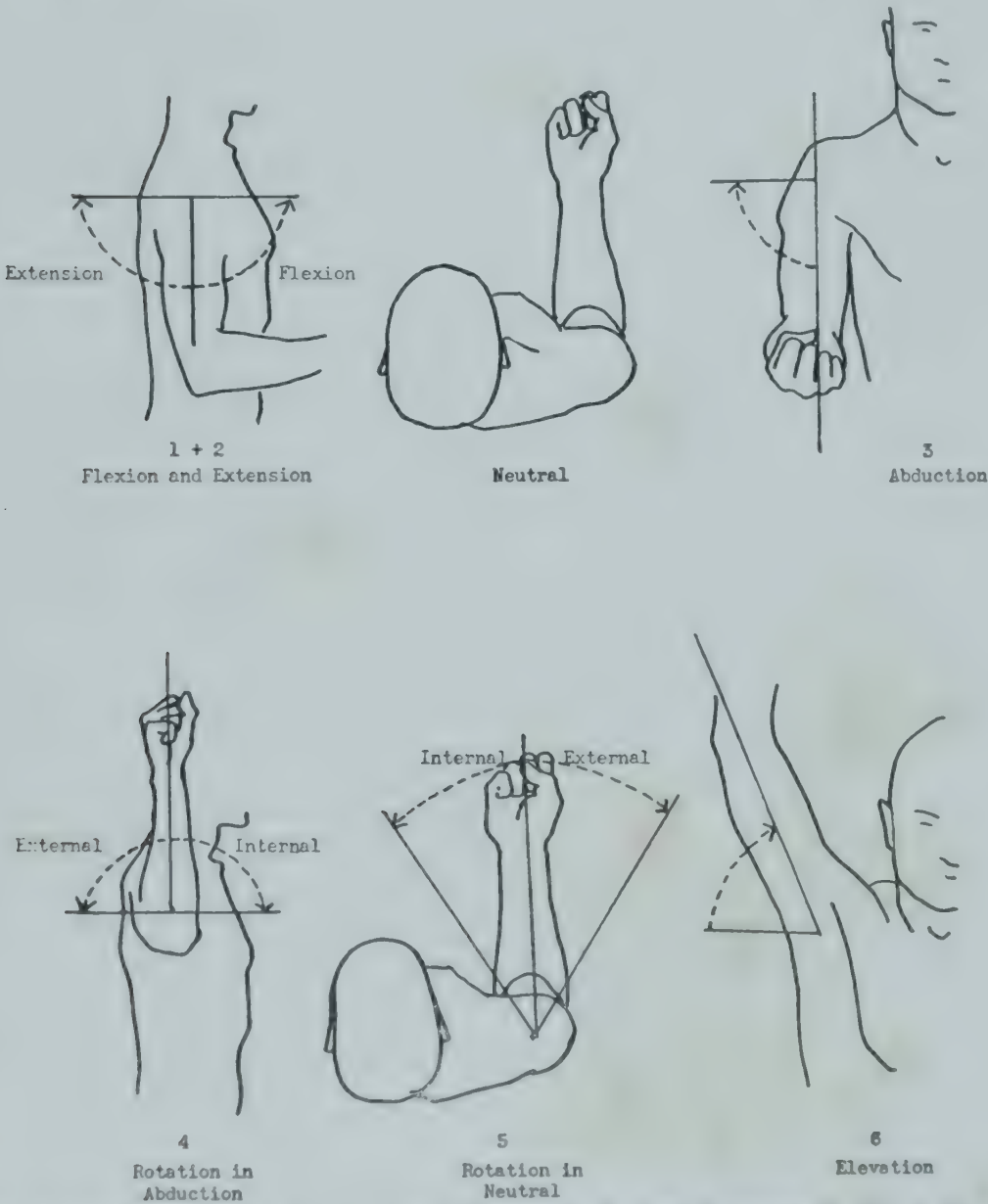


Fig. 138. Normal motion of the shoulder. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.)

Elbow

(Neutral position is with forearm in extension, and in midposition between supination and pronation)

Flexion.....	120°-130°
Extension.....	Neutral position
Supination.....	75°- 90°
Pronation.....	80°- 95°

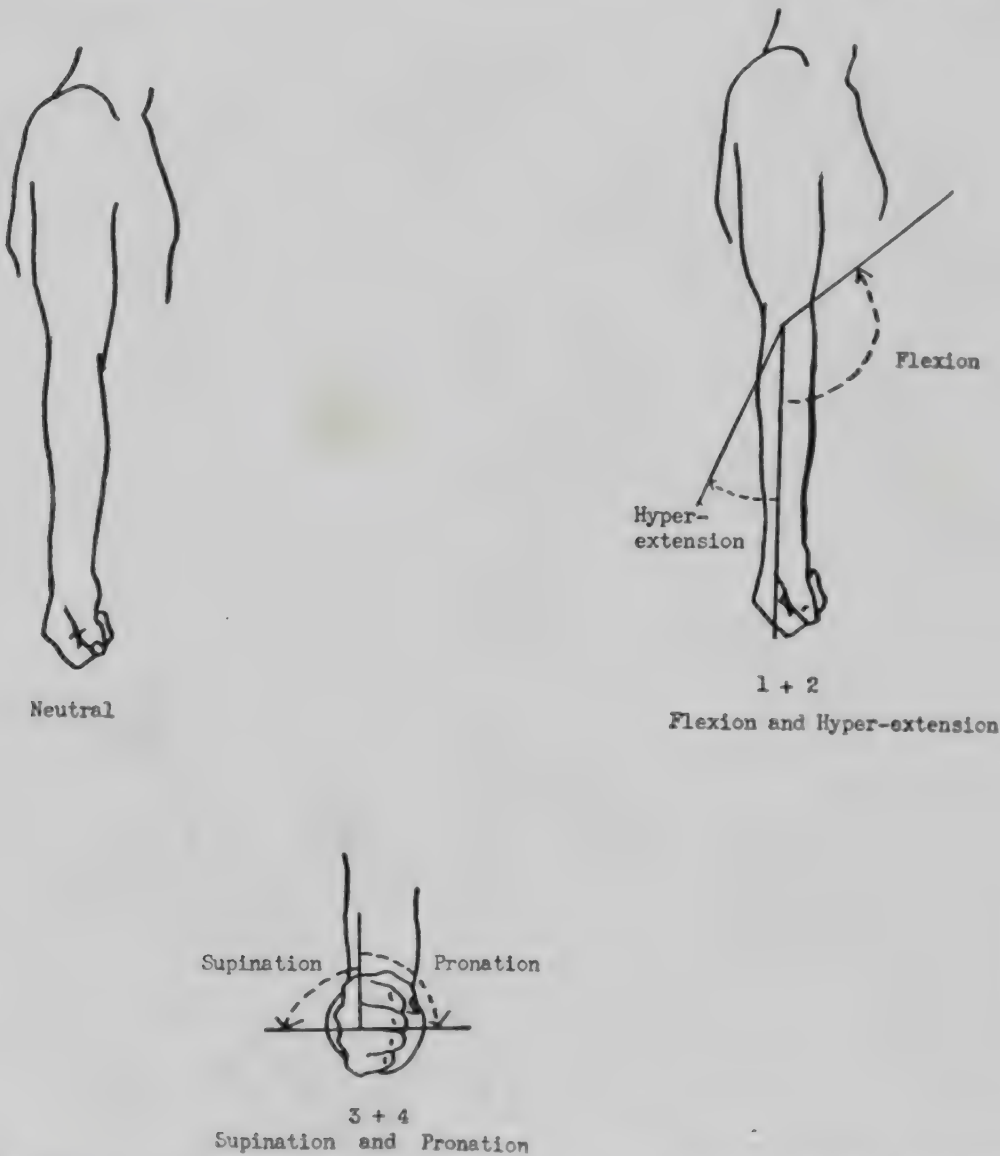


Fig. 139. Normal motion of the elbow. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.

*Wrist*

(Neutral position is with hand in line with forearm with palm down)

Dorsiflexion . . . . .	60° 90°
Palmar flexion . . . . .	60°-90°
Adduction . . . . .	40°-50°
Abduction . . . . .	20°-50°
Pronation . . . . .	80°-95°
Supination . . . . .	75°-90°

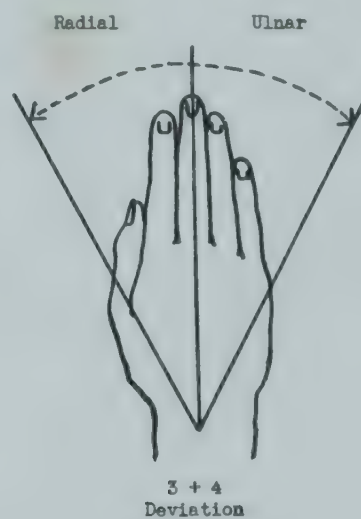
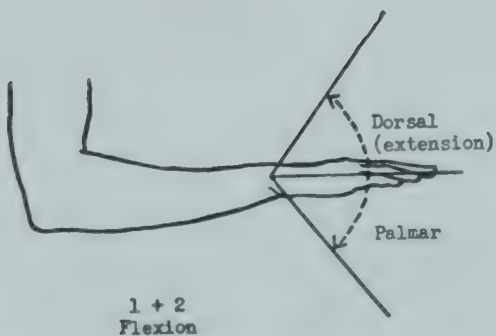
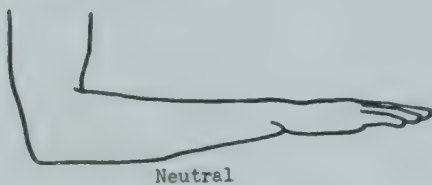


Fig. 140. Normal motion of wrist. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.

*Fingers*

(Neutral position is with fingers in extension. All motions are in flexion)

Proximal joints.....	90°-100°
Middle joints.....	110°-130°
Distal joints.....	45°- 90°

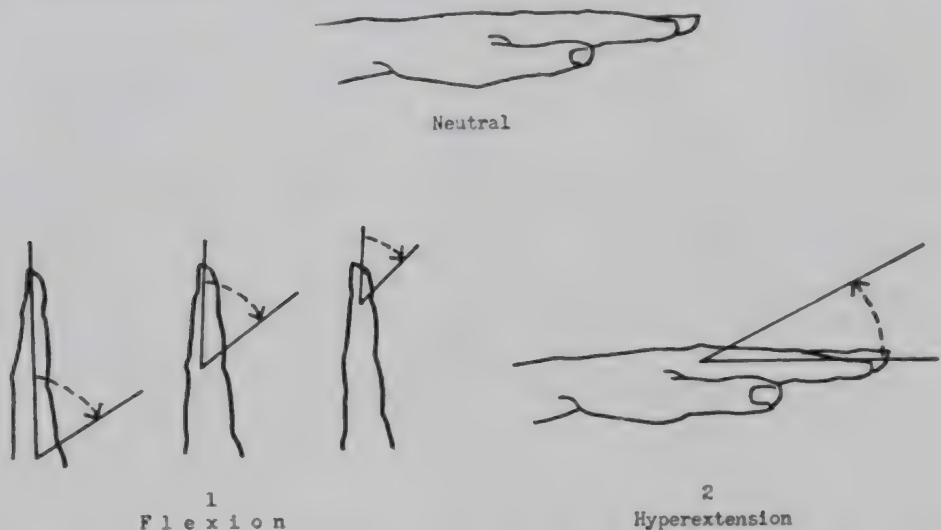


Fig. 141. Normal motion of the fingers. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.)

*Thumb*

Flexion:	
Proximal joint.....	80°-90°
Distal joint.....	70°-90°
Opposition—Tip reaches a position three inches in front of base of long finger	
Extension—Distal joint.....	5°- 10°
Abduction.....	80°-110°
Adduction—Ulnar border of hand	

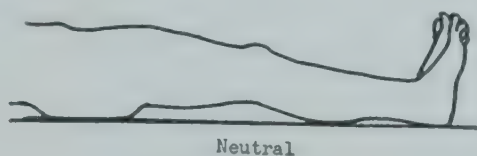


Fig. 142. Normal motion of the thumb. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.)

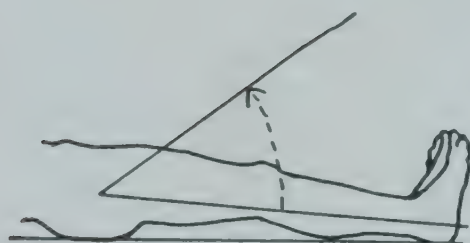
*Hip*

(Neutral position is with leg extended,

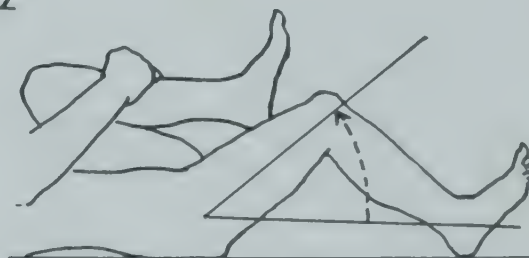
Flexion.....	120°-130°
Extension.....	20°- 45°
Abduction.....	45°- 55°
Adduction.....	30°- 45°
Internal rotation.....	30°- 45°
External rotation.....	45°- 60°



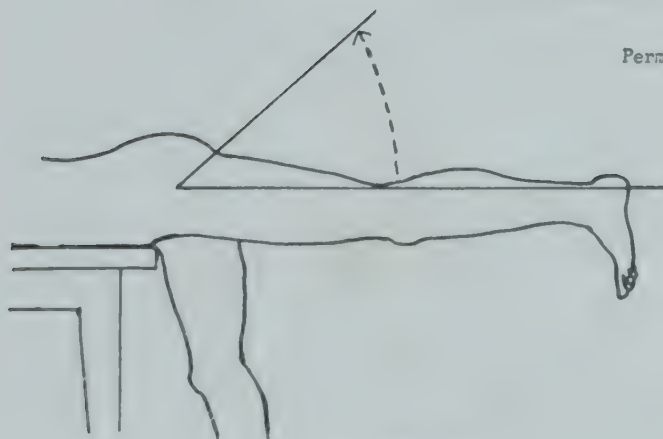
Neutral



1  
Flexion



1 A  
Permanent Flexion



2  
Hyperextension

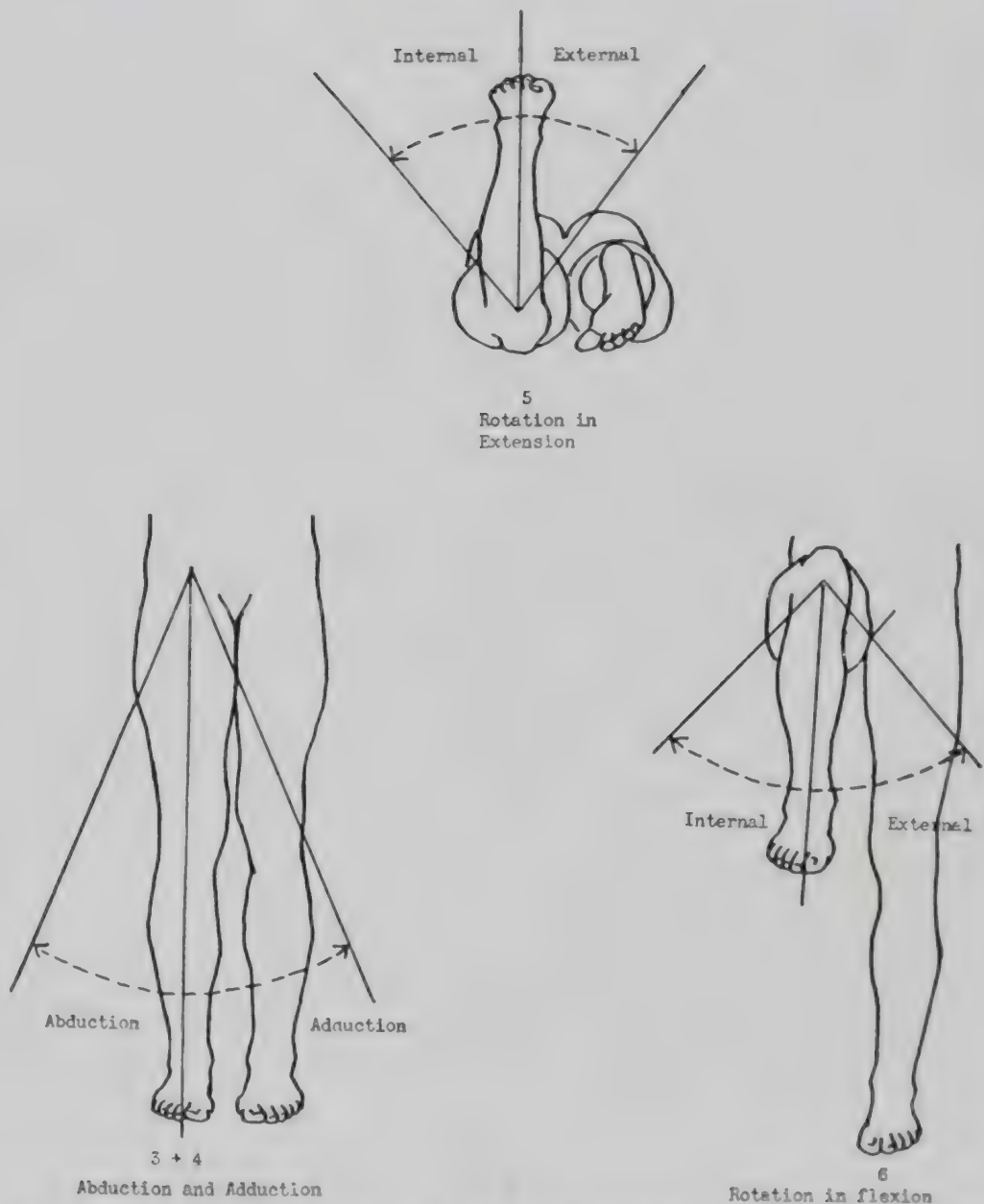


Fig. 144. Normal motion of hip. - Cave, E. F., and Roberts, S. M.: *J. Bone & Joint Surg.*, vol. 18.

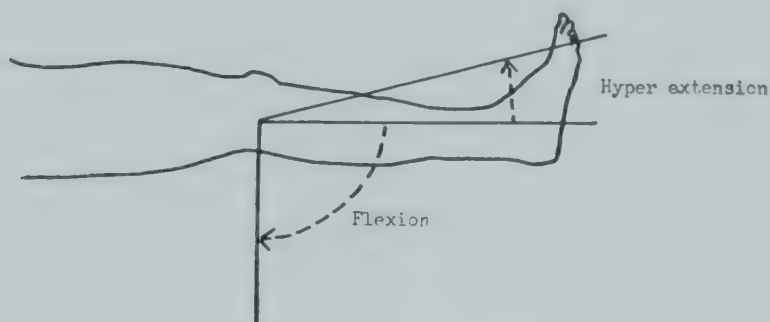
*Knee*

(Neutral position is with leg extended)

Flexion ..... 130 145  
Extension—Neutral position



Neutral



1 + 2

Flexion and Hyperextension

Fig. 145. Normal motion of knee. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.)

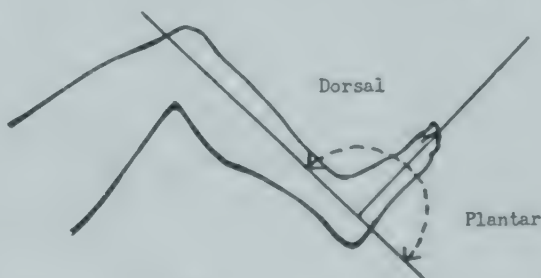
*Ankle*

(Neutral position is with foot at right angles)

Dorsiflexion ..... 10°-30°  
Plantarflexion ..... 40°-50°  
Abduction ..... 25°-35°  
Adduction ..... 35°-45°



Neutral



1 + 2

Flexion

Fig. 146. Normal motion of the ankle. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.)

Toes

(Neutral position is with toes in extension)

Metatarsophalangeal Joint

Dorsiflexion . . . . .	50° 70°
Plantarflexion . . . . .	35°-50°
Abduction . . . . .	5°-10°
Adduction . . . . .	5°-10°

Middle Interphalangeal Joint

Dorsiflexion . . . . .	0
Plantarflexion . . . . .	25°-35°

Distal Interphalangeal Joint

Remains in 20° plantarflexion  
About 5° of motion can occur

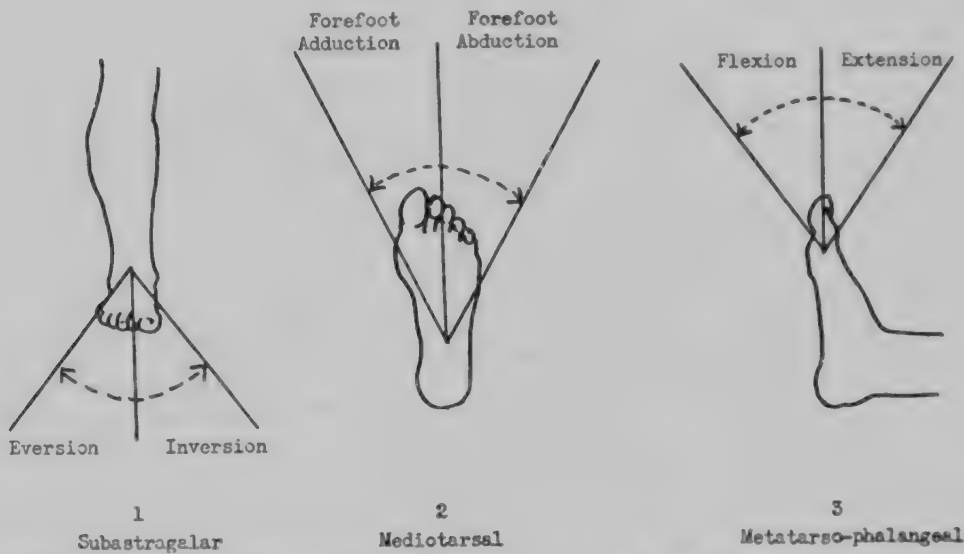


Fig. 147. Normal motion of toes. (Cave, E. F., and Roberts, S. M.: J. Bone & Joint Surg., vol. 18.

NORMAL ANATOMICAL ANGLES OF JOINTS

ANGLE OF ARTICULAR SURFACE. LOWER END OF RADIUS. A line is drawn parallel to the long axis of the radius through its midpart. A second line drawn across the articular margins of the lower radial articulation will face palmarward (Fig. 148).

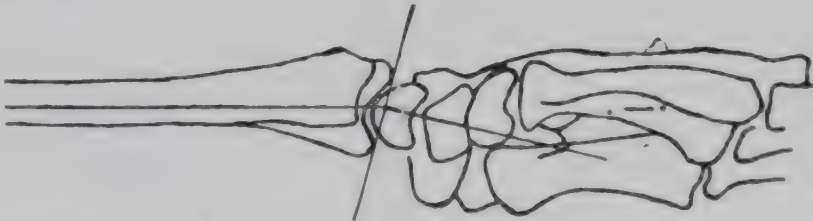


Fig. 148. Angle of articular surface, lower end of radius. (Sante, L. R.: Manual of Roentgenological Technique, Edwards Brothers.)

CARRYING ANGLE. A line drawn between the epicondyles of the lower end of the humerus is perpendicular to the shaft. The articular surface is inclined at an angle of about 10 degrees from perpendicular. This inclination of the

lower humeral articulation produces a deviation of the axis of the forearm outward from the axis of the arm when in full extension. Any loss of this angle greatly interferes with the usefulness of the extremity (Fig. 149).

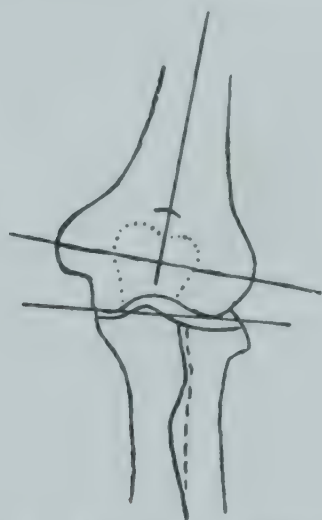


Fig. 149. Carrying angle. (Sante, L. R.: Manual of Roentgenological Technique, Edwards Brothers.)

**ANGLE NECK TO SHAFT OF FEMUR.** The neck of the femur is joined to the shaft at an angle of 125 to 130 degrees and is inclined forward at an angle of 2 degrees (Fig. 150).

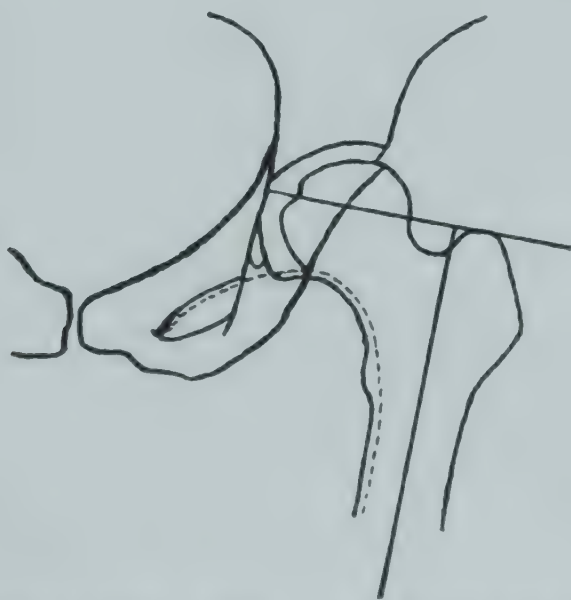


Fig. 150. Angle neck to shaft of femur. (Sante, L. R.: Manual of Roentgenological Technique, Edwards Brothers.)

**BOEHLER ANGLE OF FOOT.** Two lines are drawn through the posterior upper margin of the joint between the os calcis and astragalus, one backward to the upper margin of the os calcis, the other forward to the upper margin of the joint between the os calcis and cuboid. Normally this angle should be about 90 degrees (Fig. 151).

## SYNOVIAL FLUID

The synovial fluid keeps in close equilibrium chemically with the blood stream, owing to the fact that the synovial membrane is very permeable as compared with the choroid plexus or the glomerular membrane. It has a high viscosity due to the presence of mucin, which contributes to its lubricating

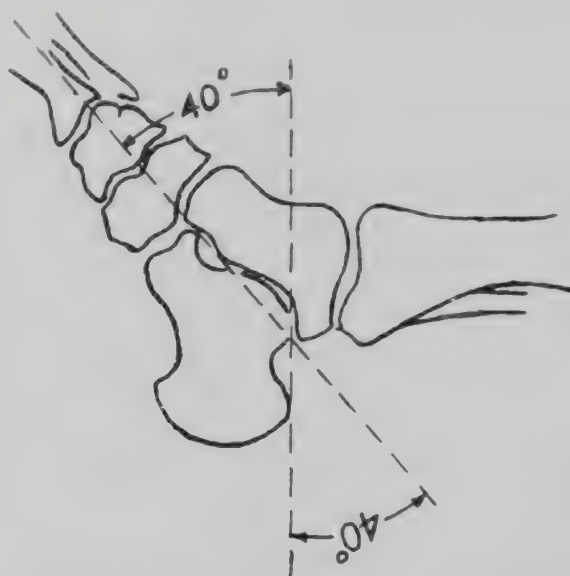


Fig. 151. Boehler's angle. (Sante, L. R.: Manual of Roentgenological Technique, Edwards Brothers.)

value. Owing to the small amount of fluid contained within the capsule of normal joints, the analytical data pertaining to synovial fluid have been limited. The values given in Table 236 are not strictly normal, since they represent measurements on nonpurulent fluids obtained from patients with arthritis (with one exception).

TABLE 236

## CHEMISTRY OF SYNOVIAL FLUID\*

(Data of Cajorie, Crouter and Pemberton,<sup>3</sup> and Forkner<sup>6</sup>)

	<i>Average</i>	<i>Range</i>
Total solids, gm./100 ml.....	6.68	6.03-7.62
Total protein, gm./100 ml.....	5.35	4.18-7.25
Total nitrogen, gm./100 ml.....	0.88	0.71-1.16
Mucin (Forkner), gm./100 ml.....	1.95	
Sugar, mg./100 ml.....	95	68-132
Nonprotein nitrogen, mg./100 ml.....	32	22-43
Uric acid, mg./100 ml.....	3.6	3.3-4.7
Lactic acid, mg./100 ml.....	21	13-28
Ash, per cent.....	0.88	0.79-1.10
Sodium chloride, mg./100 ml.....	554	409-663
Calcium, mg./100 ml.....	9.7	8.3-10.7
Total CO <sub>2</sub> , vol. per cent.....	57	43.1-68.1
pH.....	7.39	6.99-7.58
Viscosity at 20°C. (relative).....	7.6	2.7-16.7
Specific gravity (Forkner).....	1.040	
Water, gm./100 ml.....	93.3	92.4-94.0

TABLE 237  
DIFFERENTIAL CELL COUNT OF SYNOVIAL FLUID

	<i>Knee (Autopsy)</i> (Bauer et al., 1940)	<i>Knee</i> (Kling, 1938)	<i>Knee</i> (McEwen, 1935)
Total count, per cubic mm. . . . .	13-180	0-50	125-200
Monocytes, per cent . . . . .	47.9	0-20	5-10
Eosinophils, per cent . . . . .	10.1	10.1	0-13
Macrophages, per cent . . . . .	4.9	*	5-8
Lymphocytes, per cent . . . . .	24.6	5-35	8-16
Neutrophils, per cent . . . . .	6.5	0-15	7-27
Synovial lining cells, per cent . . . . .	4.3	35-60	3-7
Unclassified, per cent . . . . .	2.2	2.2	12-16

\* Recorded with monocytes.

## SKELETAL OR VOLUNTARY MUSCULATURE

From the middle of prenatal life to early maturity the growth of skeletal muscle forms the largest part of the increment of the body. The postnatal growth in muscle is somewhat similar to the growth of the body as a whole: rapid in infancy and childhood, slower but regular in middle childhood, and more rapid just before and during adolescence. The weight of the voluntary musculature of the well-developed man of medium stature is usually somewhat over 28 kg. (over 60 pounds).

The skeletal musculature forms about one-sixth of the body weight in the middle of prenatal life, one-fifth to one-fourth at birth, one-third in early adolescence and about two-fifths in early maturity.

There is no characteristic rate of muscle growth. The postnatal gain in various muscle groups varies from fivefold to fortyfold between birth and maturity. In general, the muscles of the lower extremity make the largest relative gain, those of the upper extremity come next, those of the trunk next, and those of the head make the smallest relative increment. Muscles associated with particular organs tend to grow like these organs. Thus the muscles of the genital tract show a marked increment in the puberal period, and those associated with the eyeball make practically all their limited postnatal growth in infancy and early childhood. This diversity of growth is reflected in the varied increments in size of the individual fibers of different muscles.

## BODY MECHANICS

Body mechanics has been defined as "the mechanical correlation of the various systems of the body with special reference to the skeletal, muscular and visceral systems and their neurological associations." Normal body mechanics is present when this mechanical correlation is most favorable to the function of these systems.

Correct body mechanics of muscles in relation to posture depends not on the strength of the muscles, but on the balance of strength between opposing muscle groups. Normal posture and the balance of opposing muscles in the

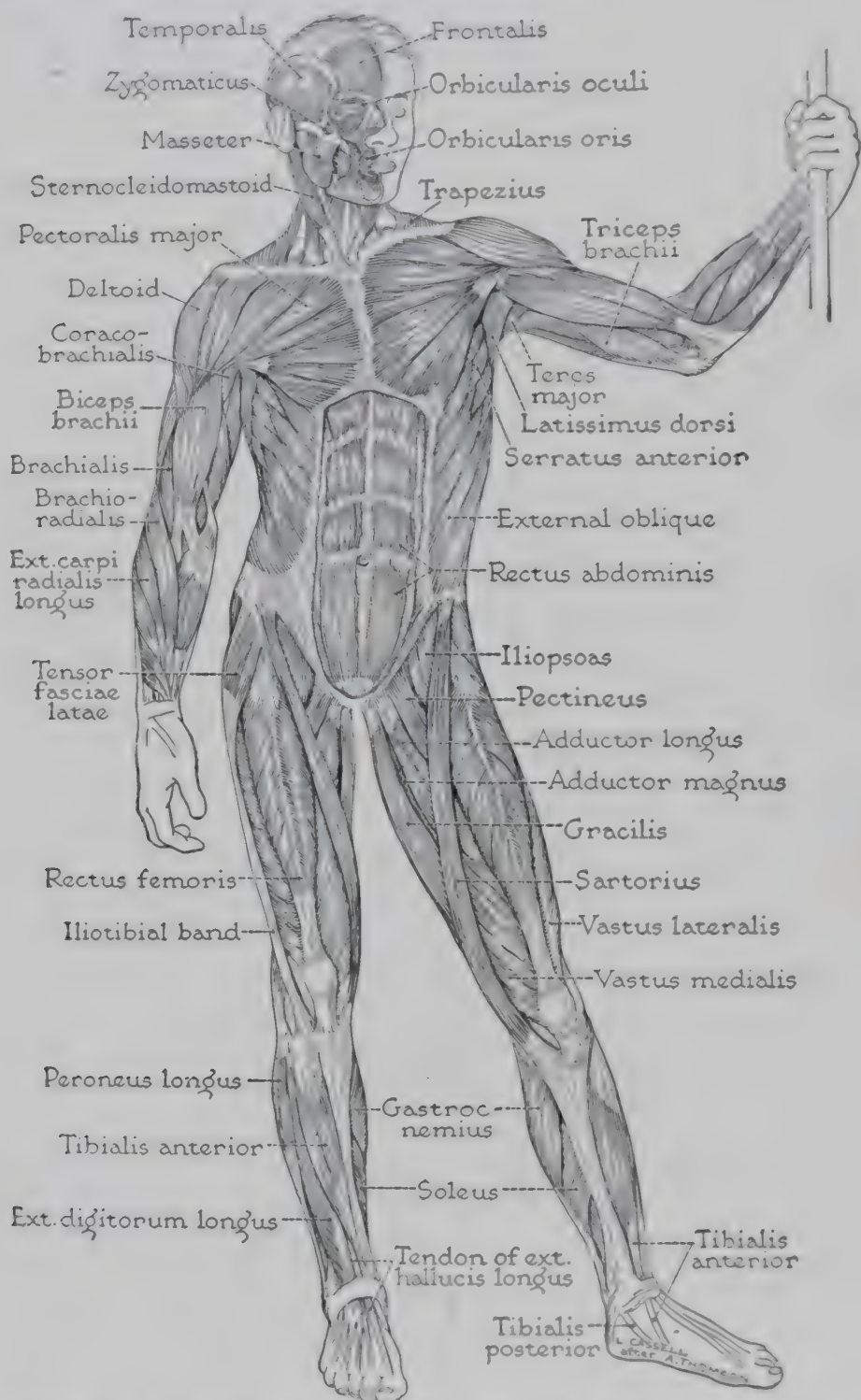


Fig. 152. Muscles of the body, anterior view. (Millard and King: Human Anatomy and Physiology.)

correct standing position may be considered in this way. The normal antero-posterior gravity line through the body passes through the lobe of the ear, the shoulder joint, the greater trochanter of the femur, posterior to the patella

and anterior to the external malleolus. The weight-bearing bony framework of the body is in the line of gravity and is maintained in that line by a balance between the anteroposterior, lateral and rotary muscle pulls.

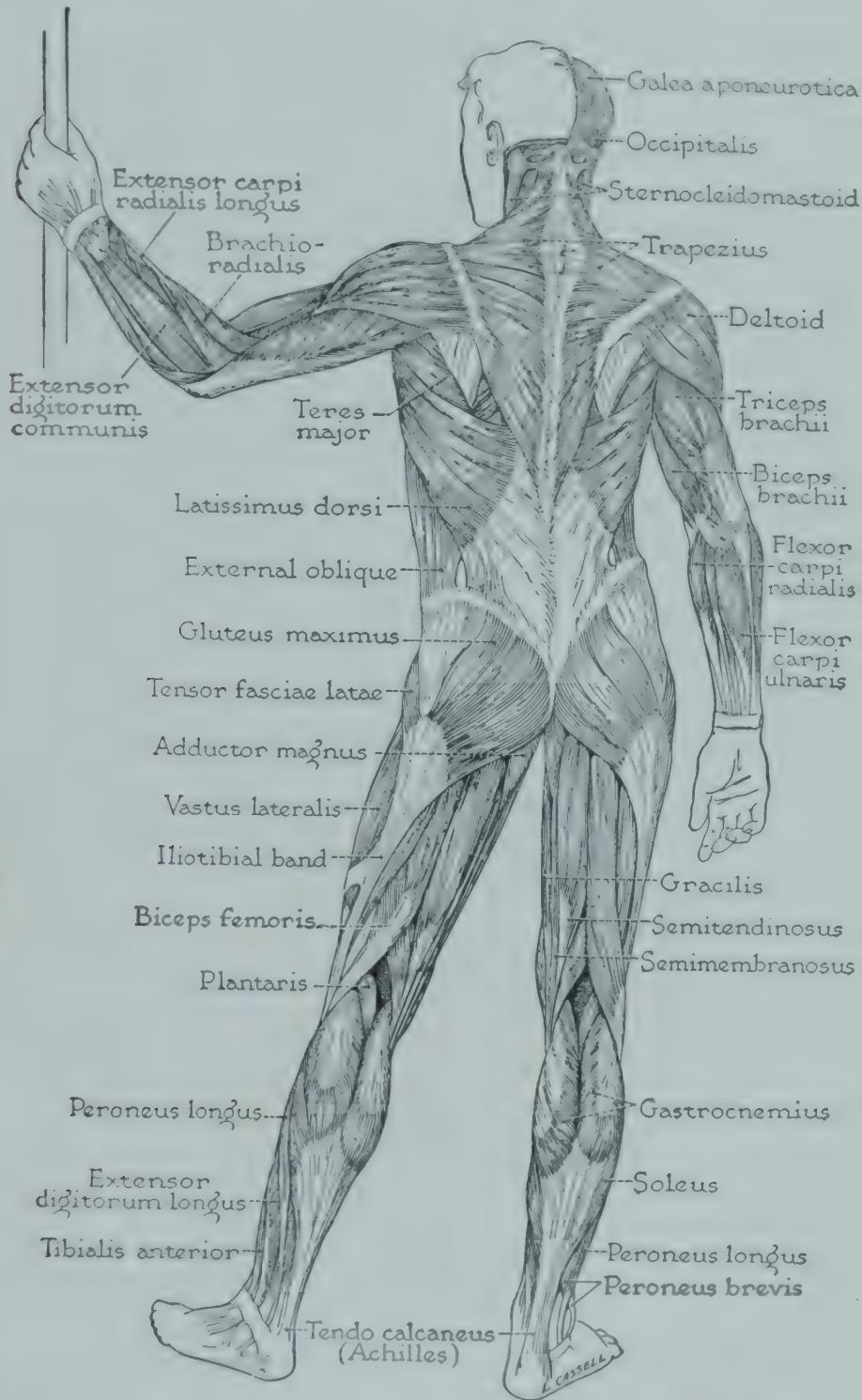


Fig. 153. Muscles of the body, posterior view. (Millard and King: Human Anatomy and Physiology.)

Not all persons are alike; therefore there are many structural differences in body build which depend on heredity and reaction to environment. The types of body build commonly recognized in the medical and anthropological liter-

ature are largely subjective in character and are not clearly defined in measurable terms. Despite these various differences there is a single type of body build which is representative of the central general tendency. This may be called the normal or intermediate type, and individuals diverging from this central tendency are atypical rather than typical.

In the intermediate type the torso is of moderate length and breadth, with the proportion of the anteroposterior diameter to the lateral diameter at the ninth rib as 2:3. The thorax is full and moderately round; the upper abdomen is rounded and of equal circumference with the thorax at the mammary line. The subcostal border forms an angle of 70 to 90 degrees. The diaphragm is high, and there is a generous space for the viscera below the lower ribs. All the abdominal viscera, except the lower part of the colon, the sigmoid, and a small part of the small intestine, are above the umbilicus. Around the viscera are well-defined masses of fat, provided for protection and support. The lower abdomen is flat, while the upper abdomen is firm and rounded, there being no marked depression below the lower border of the ribs. The ribs incline downward about 30 degrees from the horizontal.

The spine shows a mild curve forward in the lumbar region, with the apex of the curve in the midlumbar region. This produces an inclination of the abdominal cavity downward and forward about 30 degrees from the perpendicular. The sacrum is inclined downward and backward, also about 30 degrees from the perpendicular. The diagonal conjugate of the pelvis is inclined forward and downward about 30 degrees from the horizontal. The dorsal spine shows a slight backward curve with the apex of the curve in the mid-dorsal region. The long axis of the thoracic cavity should be almost perpendicular; whatever deviation there is should be in a slight forward inclination of a few degrees. There is a slight forward curve in the cervical spine.

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Section XI

THE SKIN AND ITS APPENDAGES

(Normal Values in Dermatology)



## Chapter 50

### THE SKIN

THE EXPOSED position of the skin would seem to offer an excellent opportunity for exact measurements of its normal values. Yet, except for certain determinations, there is actually a paucity of reliable uniform data on what is normal for the skin and its appendages. This is undoubtedly occasioned by the fact that the condition of the skin is rarely constant. Of all the organs (except the eye), it is unique in that it is exposed to environmental factors from without

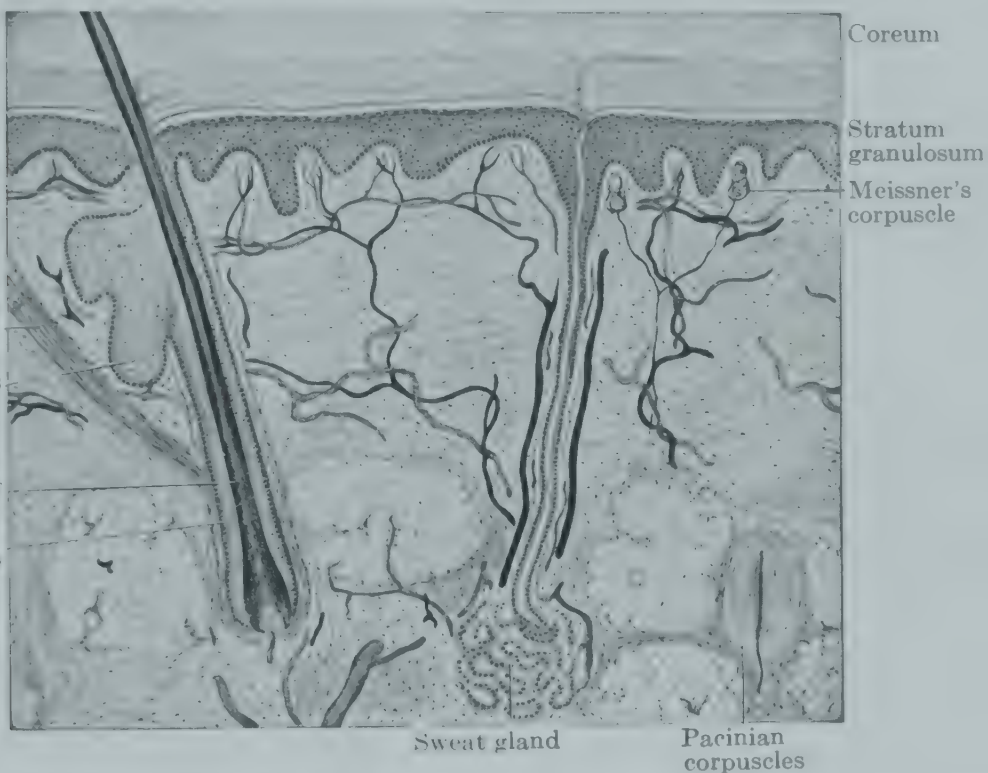


Fig. 154. Diagrammatic illustration of the anatomy of the skin and its appendages. (Andrews: Diseases of the Skin.)

as well as from within. Moreover, there are regional anatomic and physiologic differences. Many of the present data are of limited value because only recently have satisfactory methods for the separation of epidermis and dermis been perfected.

#### SURFACE AREA

Tables for skin area are in the section on Metabolism (p. 575).

#### THICKNESS

**TOTAL THICKNESS.** The total thickness varies according to race, sex, age and site. The skin of the eyelids is 0.5 mm. thick; that of the back, palms and soles, 3 to 4 mm. thick.

TABLE 238  
MEASUREMENTS OF COMPONENTS OF NORMAL HUMAN SKIN\*  
(Adapted from Engman, MacCardle and Engman, 1941)\*

Structure	Microns
Corneum (thickness) . . . . .	10
Stratum granulosum (thickness) . . . . .	8
Epidermis (interpeg) (thickness) . . . . .	40
Rete peg (length) . . . . .	30
(apical width) . . . . .	8
Fibrils (thickness) . . . . .	0.5
Intercellular canals (width) . . . . .	0.5
Spinous cell (size) . . . . .	8 by 16
Spinous nuclei (size) . . . . .	5 by 5
Basal cell (size) . . . . .	5 by 15
Blood vessels (diameter) . . . . .	5.5

\* These figures were obtained by calculating the average for 62 specimens of normal skin.

EPIDERMIS. The thickness varies from 0.07 to 0.12 mm.; that of the palm and palmar aspects of the fingers is 0.8 mm.; of the soles and toes, 1.4 mm.<sup>1</sup>  
CUTIS. The average thickness is 1 to 2 mm. It is thinner on the eyelids and prepuce (up to 0.6 mm.). On the palms and soles it is 0.3 to 2.4 mm.<sup>14</sup>

TABLE 239  
THICKNESS OF SKIN OF FACE (IN MILLIMETERS)  
(Pinkus, 1929)<sup>19</sup>

Region	Men	Women
Forehead (upper part) . . . . .	3.56	3.60
Forehead (lower part) . . . . .	4.69	4.30
Nose (root) . . . . .	4.93	4.50
Nose (middle) . . . . .	3.25	2.80
Nose (tip) . . . . .	2.5	2.07
Upper lid (root) . . . . .	11.57	9.90
Labial angle . . . . .	9.48	8.20
Mentolabial furrow . . . . .	10.05	10.4
Chin . . . . .	10.22	10.1
Beneath chin . . . . .	6.08	6.2
Middle of eyebrows . . . . .	5.65	5.3
Middle of lower margin of orbit . . . . .	4.29	4.5
Masseter of lower jaw . . . . .	8.20	7.1
Root of zygomatic arch front of ear . . . . .	6.72	6.9
Highest point of zygomatic arch . . . . .	4.33	5.3
Highest point on prominence of cheek . . . . .	6.62	7.7
Middle of masseter . . . . .	17.5	15.9
Maxillomandibular angle . . . . .	10.4	9.5

PAPILLAE

NUMBER. The total number of papillae in the average person is 150,000,000, or 100 per square millimeter of surface.<sup>22</sup>  
PROJECTION RANGE. The projection ranges from 0.001 to 0.005 mm. in width at the base and 0.02 to 0.1 mm. in height.<sup>23</sup> The papillae of the palms and soles are 0.1 to 0.2 mm. in length.<sup>25</sup>

## BLOOD VESSELS

Figure 157 shows the distribution of the blood vessels in the skin.

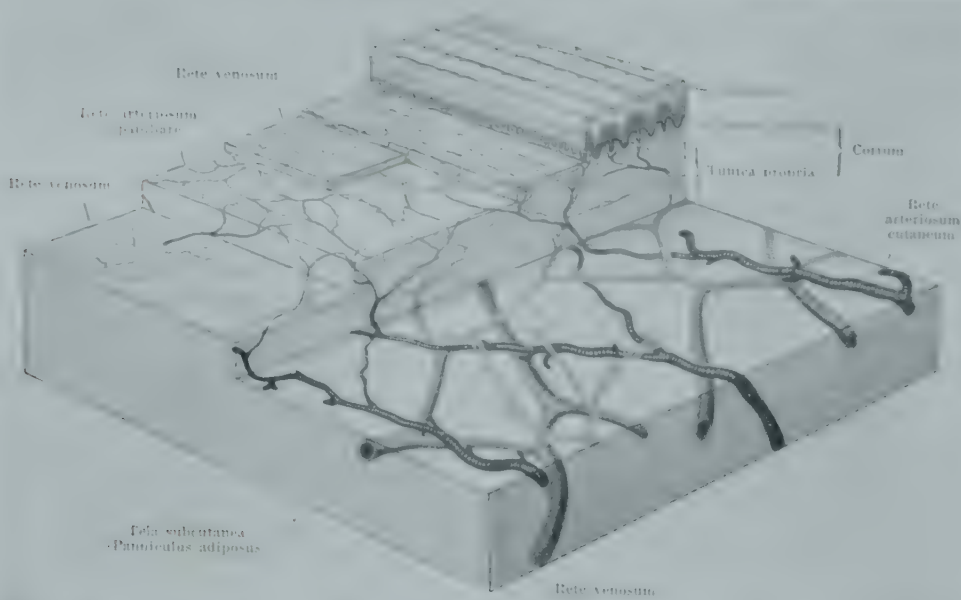


Fig. 155. Distribution of the blood vessels in the skin of the sole. (Spalteholz, W.: *Hand Atlas of Human Anatomy*, vol. 3, J. B. Lippincott Company.)

## NORMAL COLOR

The fundamental hue or dominant wavelength of skin lies in the spectral region of 589 millimicrons (sodium yellow). The formation of melanin decreases the brilliance, because the more melanin, the lower the percentage of light reflected from the surface. Color depends on the thickness of the upper layers of the epidermis, pigment, transparency of the upper layers, blood vessel distribution and blood content.<sup>24</sup>

## DISTRIBUTION OF CAROTENE

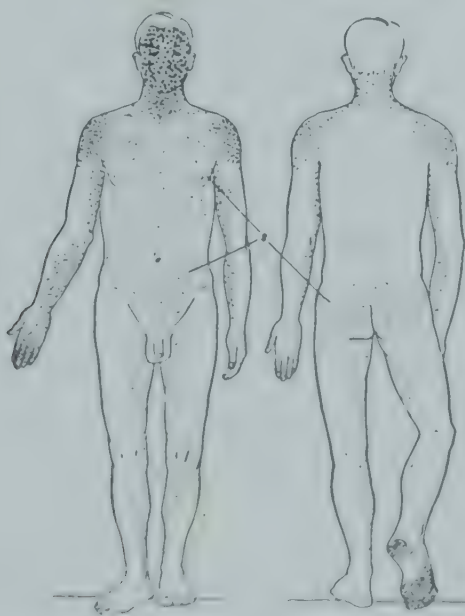


Fig. 156. The bodily distribution of carotene. The unshaded areas were particularly poor in carotene. (Edwards, E. A., and Duntley, S. O.: *Am. J. Anat.*, vol. 65.)

The pigments normally present in the skin are melanoid, carotene, reduced hemoglobin, oxyhemoglobin and melanin.

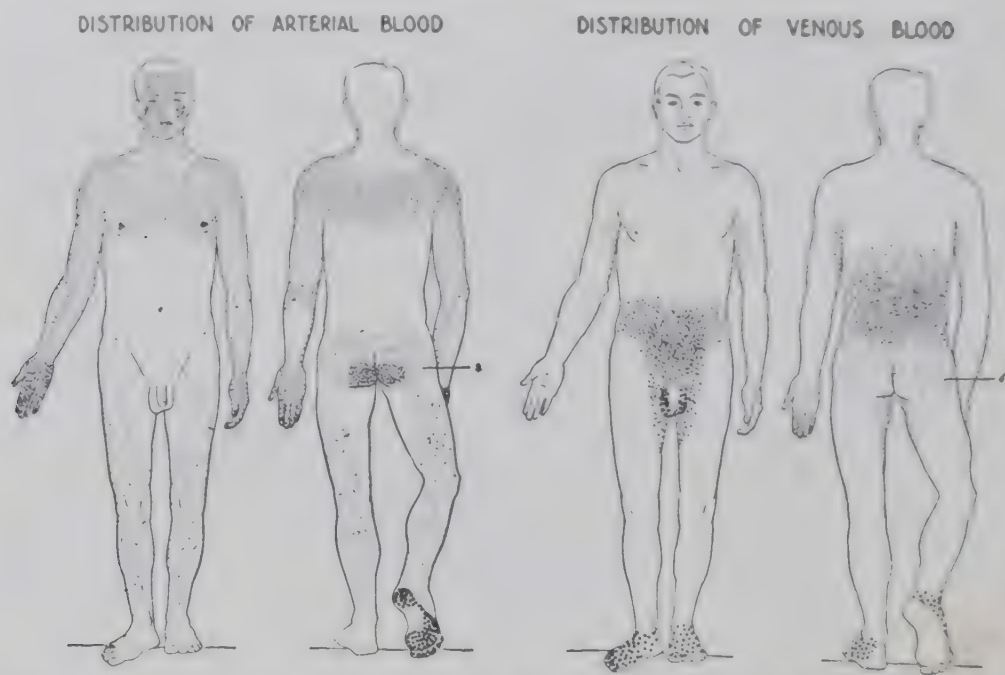


Fig. 157. The bodily distribution of arterial and venous blood. In each chart are indicated areas where the blood is predominantly venous or arterial. (Edwards, E. A., and Duntley, S. O.: *Am. J. Anat.*, vol. 65.)

AGING OF SKIN

“If there is any part of the body which literally thrusts the evidence of its advancing years upon whomsoever may look, it is the skin.”\*

Measurements of epidermal thickness from basal to granular layers in the areas between rete ridges showed old epidermis thinner than young epidermis by 6.5 microns. Old skin also has a tendency to lose a layer of granular cells, and the corneum appears thinner.<sup>10</sup>

TABLE 240  
RECONCILIATION OF PROCESSES AND SYMPTOMS IN AGING  
(Weidman, 1939)<sup>31</sup>

Process	Symptoms
Purity of Aging Unquestionable	
Atrophy (hair papilla) .....	Baldness
Atrophy (hair papilla) .....	Graying of hair
Degeneration and loss of elastic tissue .....	Wrinkles
Atrophy (epiderm) .....	Thinning of skin with smoothness (scaliness corollary)
Atrophy (epiderm) .....	Dystrophy of toenails
Withdrawal of subcutaneous fat .....	Leanness and wrinkles
Purity Questionable	
Secondary to degeneration of collagenous tissue (?)	Telangiectasia
Epidermal hyperplasia .....	Seborrheic keratosis
General endocrine interrelationship (?) .....	Hyperpigmentation
Sebaceous hyperplasia .....	Yellowness, large pores
Hyperplasia of fibrous tissue with degeneration	Cutaneous tags (acrochordon)
Epidermal hyperplasia .....	Senile keratosis
Epidermal hyperplasia .....	Cancer

\* F. D. Weidman in *Cowdry's Problems of Ageing*.

## TEMPERATURE

The ability of the skin to lose heat (thermal conductance) may vary between 10 and 40 calories per square meter per degree Centigrade. Variations depend on the state of the cutaneous circulation, the thickness of the epiderm, stratum corneum and fat, and the presence of folds.

TABLE 241  
TOPOGRAPHY OF SKIN TEMPERATURE  
(From Oehler, 1904)<sup>17</sup>

	<i>Skin Temperature*</i> (Degrees C.)	
	Maximum	Minimum
Forehead.....	35.2	33.8
Cheek.....	35.5	33.8
Breast.....	35.3	33.8
Abdomen.....	36.0	34.2
Upper arm.....	34.7	33.1
Forearm.....	34.8	31.7
Dorsum of hand.....	34.8	32.5
Thigh.....	35.0	32.8
Leg.....	35.1	32.4
Dorsum of foot.....	35.2	29.3

\* Environmental temperature was always 20° to 21° C.; rectal temperature about 37° C.

TABLE 242

SKIN TEMPERATURES OF NORMAL CHILDREN AT ROOM TEMPERATURE (20° TO 22.5°C.)\*  
(Figures calculated from those given by Talbot, 1931)

<i>Region</i>	<i>Range in Degrees C. (2 × S.D.)</i>
Forehead.....	31.17-34.83
Cheek, right.....	28.76-35.24
Cheek, left.....	30.17-33.83
Supraclavicular notch.....	32.91-35.49
Midsternum.....	33.42-35.78
Just above ensiform.....	33.28-36.52
Halfway from sternum to umbilicus.....	34.22-36.58
Halfway from umbilicus to pubis.....	34.11-36.69
Just above pubis.....	34.32-36.68
Thigh, front, right.....	32.78-36.02
Thigh, front, left.....	32.68-35.92
Dorsum of foot, right.....	25.02-35.38
Dorsum of foot, left.....	23.86-35.74
Hand, right.....	31.16-35.04
Hand, left.....	31.26-35.14

\* Twenty-nine determinations made on 10 subjects whose ages ranged from 3½ months to ½ years.

## ABSORPTION BY THE SKIN

(Permeability and Absorptivity of the Skin)

Overton's rule, which postulates that lipid-soluble substances enter the living cells and that lipid-insoluble ones do not, is largely valid as far as percutaneous absorption is concerned. The impermeability of the skin to water and electrolytes is caused neither by the presence of a greasy or waxy cover of the skin nor by the presence of the horny layer. The seat of the absorption barrier is in the transitional layers between cornified and noncornified epi-

thelium, i. e., in the stratum granulosum and stratum lucidum, which represent an electric double layer with positive hydrogen ions on the outside and negative hydroxyl ions on the inside. The presence of appendages in the skin complicates the mechanism of percutaneous absorption, mainly because any substance may penetrate into the follicular canal and reach the duct of the subaceous gland and from there the gland cells, thus avoiding the passages through a stratified epithelium and directly contacting cells whose permeability is higher than that of the granular layer of the epidermis. If there is any absorption of lipoid-insoluble electrolytes, the route is through the appendages.<sup>21</sup>

Eller and Wolff<sup>8</sup> give the permeability and absorptivity of the skin as follows:

1. Medicaments applied to the unbroken skin may be absorbed into the blood stream.
2. The rate of absorption may be influenced by the vehicle as well as by the drug it contains.
3. Volatile substances, such as alcohol, ether and benzene, are vehicles with a much higher rate of absorption than fats.
4. Fats permeate the skin, in a large measure along the hair shafts and into the oil gland ducts.
5. Liquid fats permeate the skin more rapidly than do solid fats.
6. Animal fats show the greatest depth of penetration, with vegetable fats next and mineral fats least.
7. Most fats show optimum penetration four to six hours after application. After six hours the quantity of fat in the deeper tissues appears to diminish.
8. Androgens and estrogens applied in solution or ointment are readily absorbed through the intact skin.
9. By cutaneous application hormones can cause systemic effects similar to those observed after ingestion or injection of these substances; in some instances the effects are greater by percutaneous absorption.
10. Vitamins D, A and C can be absorbed through the unbroken skin.
11. There is no proof that the topical application of vitamins has any local effect on the unbroken skin.

### COLD, WARM AND PAIN POINTS

Tables 243, 244, 245 and 246 give the cold points, warm points and pain points of the skin.

TABLE 243

#### DENSITY OF COLD POINTS

(Porz and Stronghold, cited by Frey and Rein, 1929)<sup>11</sup>

Region	Number per Sq. Cm.
Facial skin . . . . .	11 3
Scalp and neck . . . . .	9 0
Trunk . . . . .	9 7
Upper extremity (excluding hand) . . . . .	6 0
Hand . . . . .	4 0
Upper extremity (including hand) . . . . .	5 6
Lower extremity . . . . .	5 0

TABLE 244

AVERAGE DENSITY OF WARM POINTS OF DIFFERENT PARTS OF THE BODY  
(Rein, 1925)<sup>20</sup>

<i>Region</i>	<i>Density in Sq. Cm.</i>
Forehead . . . . .	0.62
Nose . . . . .	1.00
Face . . . . .	1.70
Breast . . . . .	0.30
Arm (middle) . . . . .	0.20
(Flexor surface) . . . . .	0.30
(Elbow fossa) . . . . .	0.70
Forearm (dorsum) . . . . .	0.33
(Volar) . . . . .	0.40
Hand (dorsum) . . . . .	0.54
(Volar) . . . . .	0.45
Finger (dorsum) . . . . .	1.75
(Lateral) . . . . .	2.00
(Volar) . . . . .	1.60
Thigh . . . . .	0.39

TABLE 245

DENSITY AND THRESHOLD OF PAIN POINTS AT VARIOUS REGIONS OF THE BODY  
(Strughold, 1924)<sup>26</sup>

<i>Location</i>	<i>Number per Sq. Cm.</i>	<i>Mean Threshold in Grams (Stachelborsten)*</i>
Hairy scalp . . . . .	144	1.35
Frontal region . . . . .	184	0.53
Dorsum of nose . . . . .	108	0.95
Tip of nose . . . . .	44	1.00
Chin . . . . .	196	0.55
Cheek . . . . .	180	0.58
Ear lobe . . . . .	168	0.48
Ear anthelix . . . . .	136	0.57
Ear lobule . . . . .	76	0.78
Eyelids . . . . .	172	0.18
Hyoid region . . . . .	204	0.48
Jugular fossa . . . . .	228	0.26
Supraclavicular fossa . . . . .	212	0.28
Neck at hairline . . . . .	176	0.65
Medial brachial region . . . . .	208	0.29
Lateral brachial region . . . . .	200	0.46
Elbow . . . . .	224	0.27
Volar region of forearm . . . . .	203	0.32
Dorsal region of forearm . . . . .	196	0.51
Dorsal region of hand . . . . .	188	0.66
Thumb . . . . .	60	2-4
Inguinal region . . . . .	220	0.38
Anterior femoral region . . . . .	192	0.66
Posterior femoral region . . . . .	176	0.60
Popliteal region . . . . .	232	0.30
Anterior crural region . . . . .	172	0.70
Posterior crural region . . . . .	160	0.56
Dorsal aspect of foot . . . . .	168	0.68
Sole . . . . .	48	2-4

\* Instrument used for testing similar to Frey's esthesiometer.

TABLE 246

THRESHOLD FOR SHARP AND DULL PAIN IN RESPONSE TO COLD AT VARIOUS REGIONS OF THE BODY

(Schriever, 1928)<sup>23</sup>

<i>Location</i>	<i>Sharp Pain (Degrees C.)</i>	<i>Dull Pain (Degrees C.)</i>
Midline of forehead.....	+ 8	+ 14
Supraorbital foramen.....	+ 9	+ 16
Temporal region.....	+ 10	+ 16
Infraorbital foramen.....	+ 10	+ 14
Zygoma.....	+ 10	+ 10
Insertion of nose.....	+ 8	+ 14
Tip of nose.....	+ 10	0
Upper lip, middle.....	+ 12	+ 2
Lower lip, middle.....	+ 12	+ 6
Cheeks, mouth line, medial.....	+ 10	+ 4
Cheeks, mouth line, lateral.....	+ 10	+ 2
Chin, middle.....	+ 10	+ 2
Mental foramen.....	+ 10	+ 10
Tip of ear.....	- 4	0
Ear lobule.....	- 4	+ 4
Mastoid region.....	+ 10	+ 4
Skull, region of large fontanelle.....	+ 6	+ 4
Process spinosus of 3rd lumbar vertebrae.....	+ 10	- 12
Loin.....	+ 10	+ 8
Coccygeal region.....	+ 10	+ 12
Gluteal region.....	+ 8	- 4

DERMATOMES

Figures 158, 159 and 160 show the dermatomes and the segmental innervation of the skin.

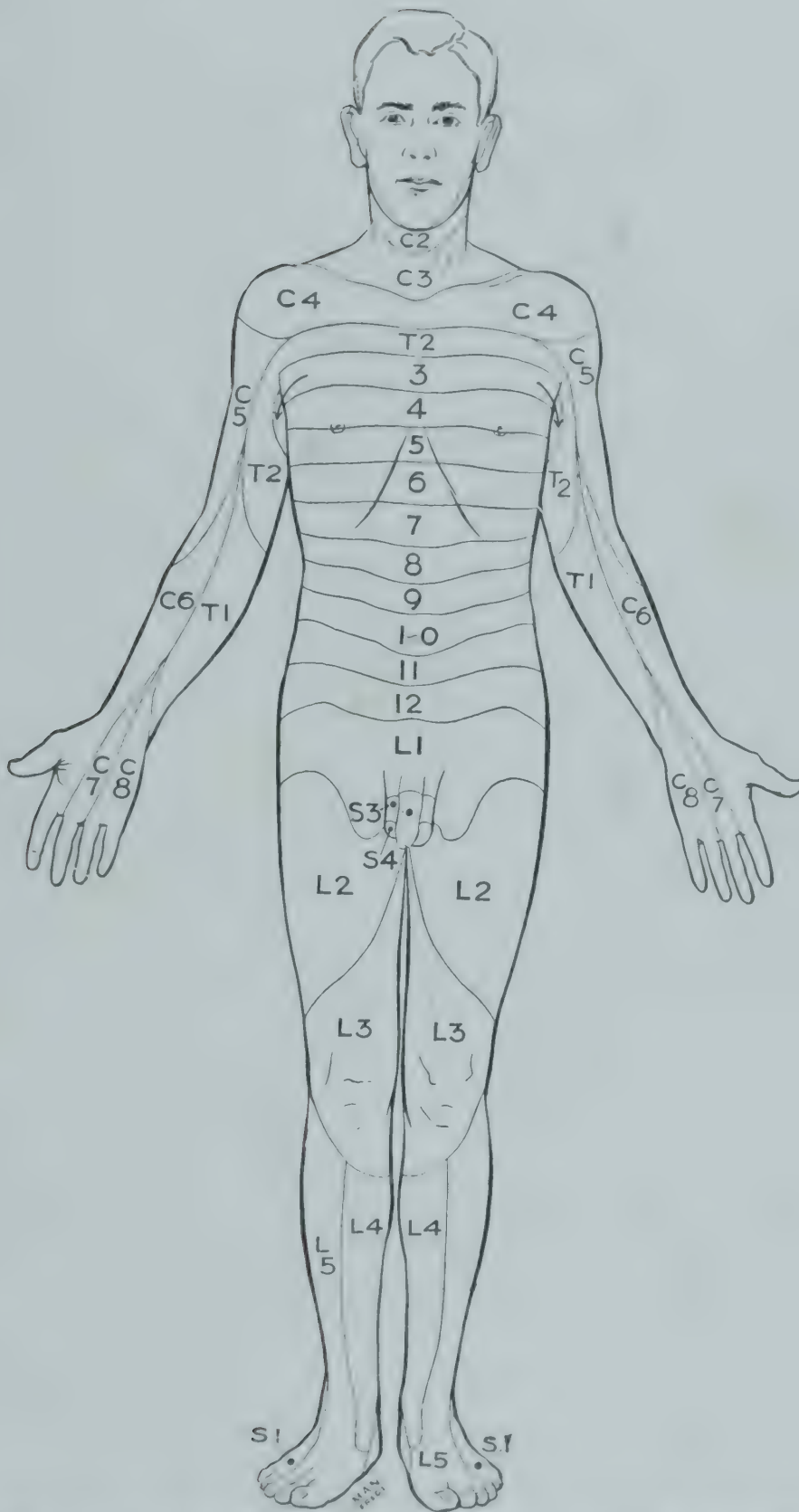


Fig. 158. The segmental innervation of the skin from the anterior aspect. The uppermost dermatome adjoins the cutaneous field of the mandibular division of the trigeminal nerve. The arrows indicate the lateral extensions of dermatome T3. (After Foerster. Haymaker and Woodhall: *Peripheral Nerve Injuries*.)

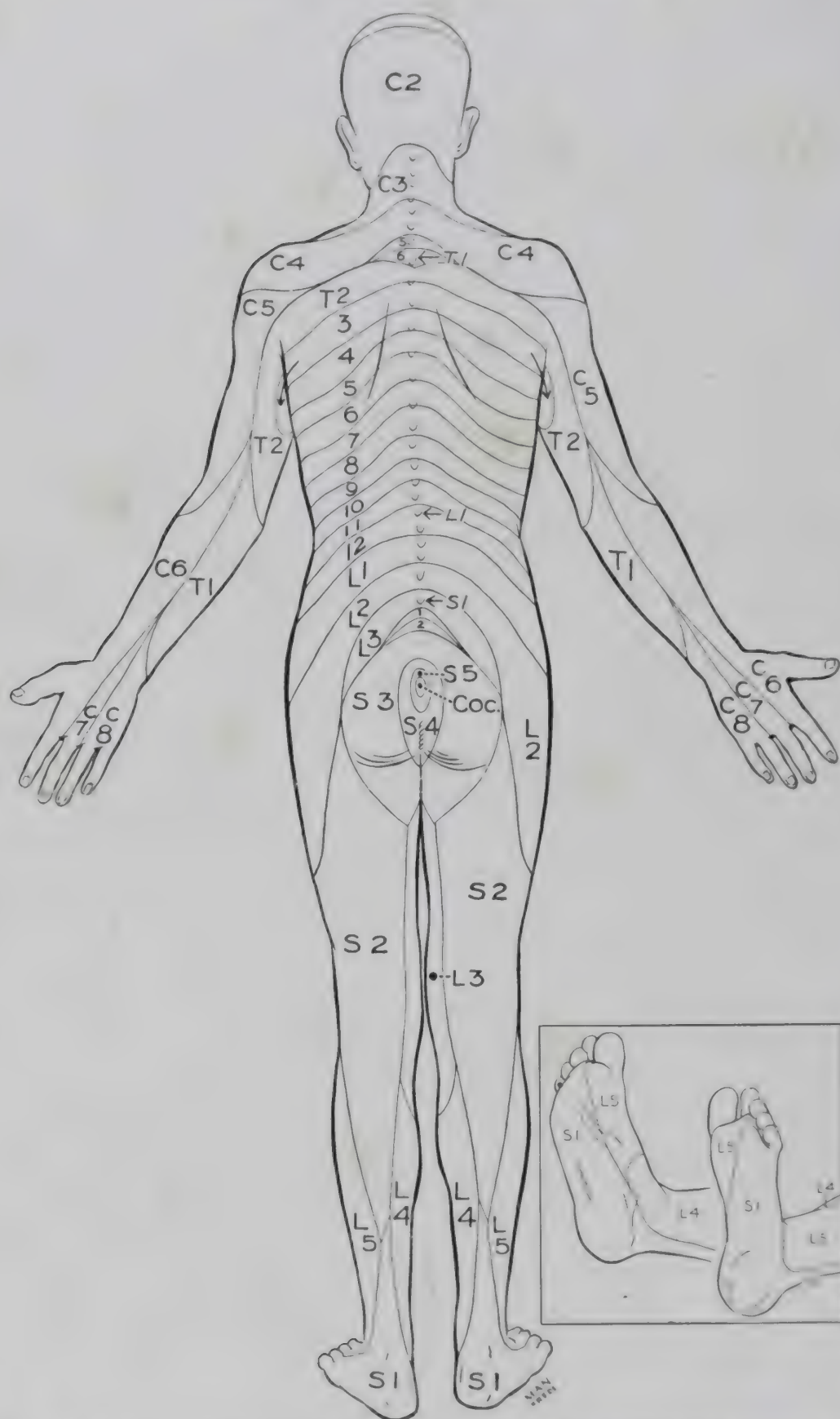
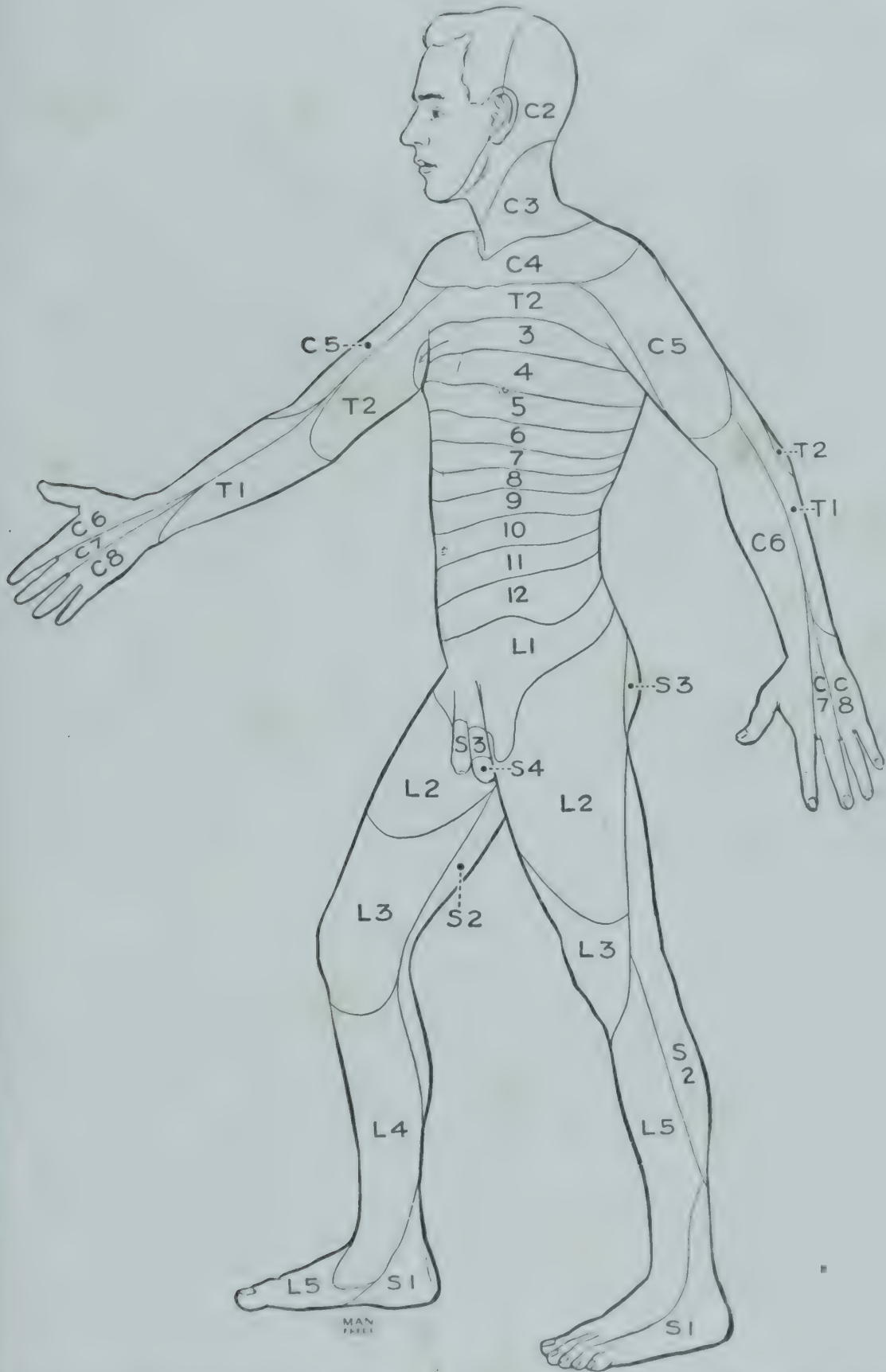


Fig. 159. The dermatomes from the posterior view. Note the absence of cutaneous innervation by the first cervical segment. Arrows in the axillary regions indicate the lateral extent of dermatome T3; those in the region of the vertebral column point to the first thoracic, the first lumbar and the first sacral spinous processes. (After Foerster. (Haymaker and Woodhall: Peripheral Nerve Injuries.)



g. 160. A side view of the dermatomes. (After Foerster. (Haymaker and Woodhall: Peripheral Nerve Injuries.)

## LINES OF NORMAL TENSION (LANGER'S LINES)

Figure 161 shows the lines of normal tension (Langer's lines) of the skin.

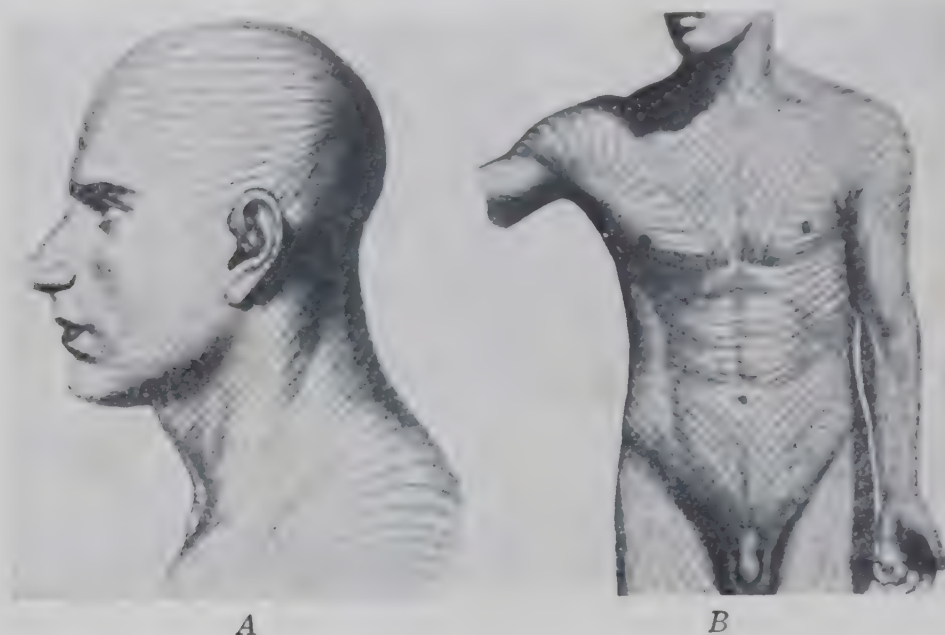


Fig. 161. These illustrations show the lines of normal tension of the skin known as the lines of Langer. Incisions through the skin across these lines will gape wider than those cut parallel to them, and incisions closed parallel to these lines will be less likely to cause wide scars than those closed across them. The elastic tissue of the corium throws the papillary layer into definite folds which cause these patterns. The epithelium plays no part in the formation of these folds, since it merely covers the corium beneath. These patterns are practically uniform, with only minor individual variations. A, Langer's lines of normal skin tension on the head and neck; B, Langer's lines of normal skin tension on the front of the trunk and upper extremity. This illustration is redrawn from Kirschner and Schubert (*Allgemeine und spezielle chirurgische Operationslehre*, Berlin, Julius Springer, vol. 1).

## SKIN RESPIRATION

The variation in the respiration of the skin of different normal persons, as determined by the Warburg apparatus, is illustrated in the following set of values (from a position about 6 inches [15 cm.] below the axilla in the midaxillary line). The subjects were white women between twenty and thirty years of age. The  $QO_2$ \* values were 2.02, 2.24, 1.16, 0.87, 1.99, 1.26, 1.07, 1.21, 2.36, 1.26, 2.08, 0.63, 1.13, 1.21, 2.34, 1.28 and 1.13; average  $QO_2$  equals 1.48 plus or minus 0.48. It is evident that within the age limits chosen a considerable individual variation occurs. In the seventeen experiments a variation of from 0.63 to 2.36 was found.<sup>1</sup> Amersbach and his co-workers<sup>2</sup> measured the oxygen uptake of normal human skin in the Warburg apparatus. The  $QO_2$  values ranged between 2.36, maximum, and 0.44, minimum (the epidermis was not separated from the dermis).

Wohlgemuth and Klopstock<sup>34</sup> determined the oxygen consumption of fresh human skin obtained at operations from ten persons. The subjects were both

\*  $QO_2$  = cubic millimeters of oxygen taken up per milligram of tissue (dry weight) per hour.

men and women and varied in age from twenty-two to sixty-seven years. These investigators found an average  $QO_2$  of 2.1, varying between 1.0 and 3.6.

Von Gerlach (cited by Amersbach<sup>2</sup>) gives the quantity of oxygen absorbed by the skin at about 1/137th of that passing through the lungs. He gives carbon dioxide as 1/25 to 1/92 of that passing through the lungs.

### CAPILLARY BLOOD PRESSURE

The blood pressure of the capillaries varies according to indirect methods from 1.5 to 71 mm. of mercury. In direct methods (cannula), with the hand at

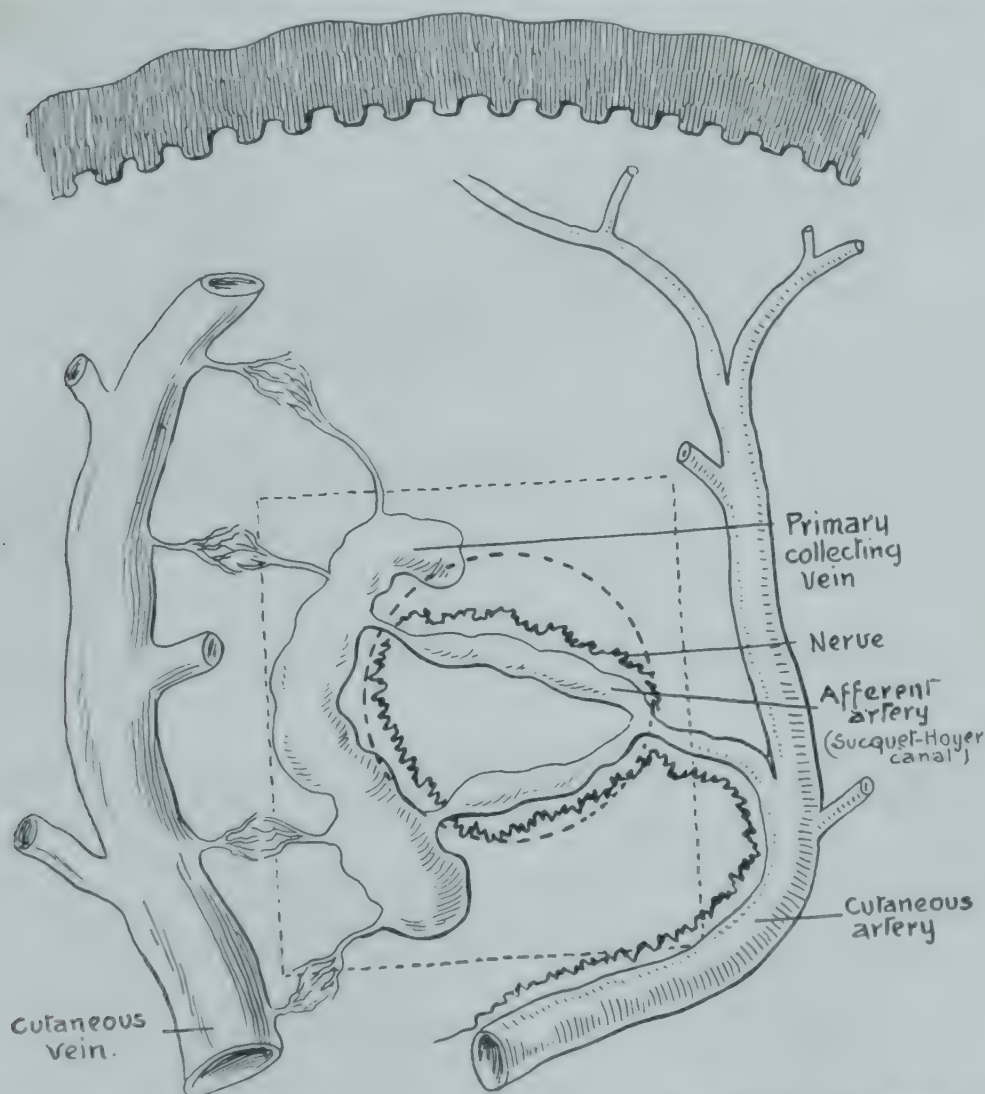


Fig. 162. Schema of normal glomus (in dotted square). The portion in the dotted circle enlarged in Figure 163. (Weidman, F. D., and Wise, F.: Arch. Dermat. & Syph., vol. 5.)

the heart level, the pressure at the arteriolar end of the capillary loop averages 2 mm. as compared with the venous end.<sup>15</sup>

### LYMPHATICS OF THE SKIN

The human skin has a close network of minute lymphatics. Hudack and McMaster<sup>16</sup> developed a method whereby these vessels can be demonstrated

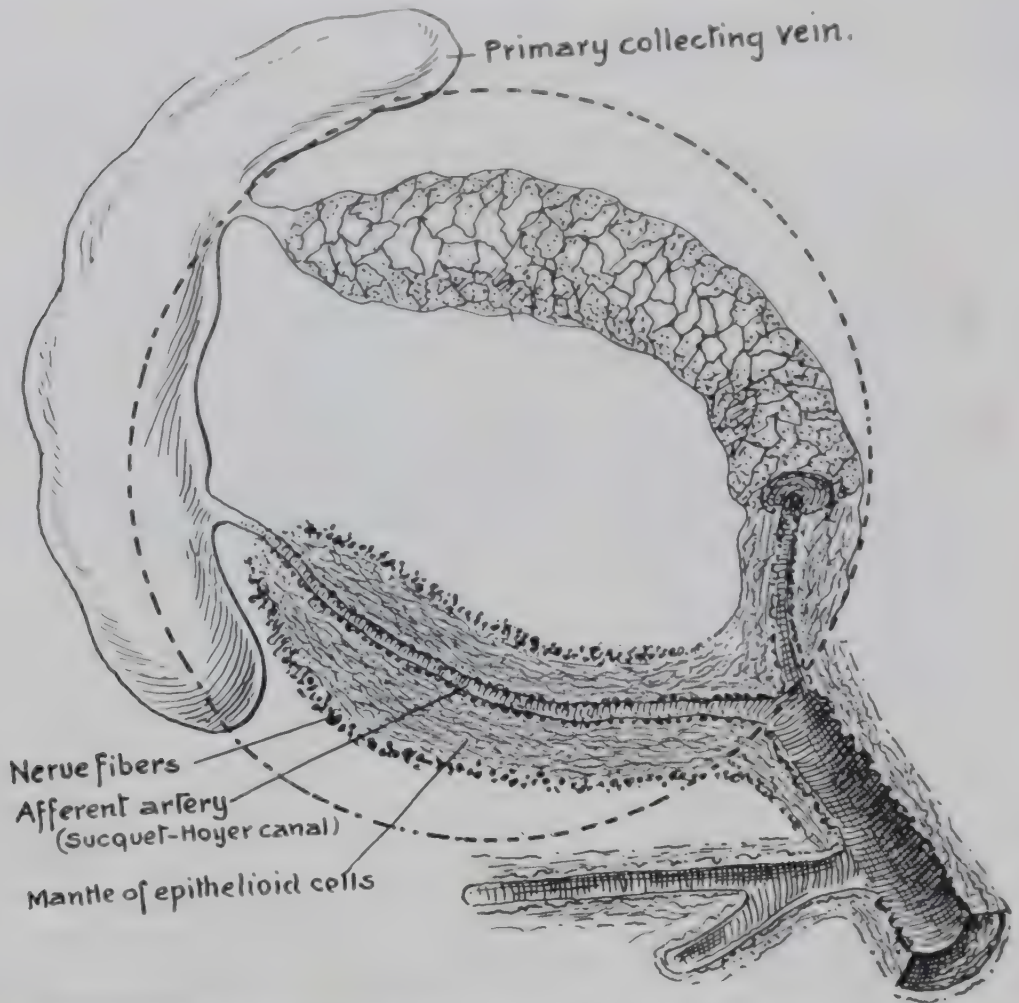


Fig. 163. Portion of the normal glomus illustrated in Figure 162. The part in the dotted circle is most distinctive histologically and is of greatest value in histologic studies. (Weidman, F. D., and Wise, F.: *Arch. Dermat. & Syph.*, vol. 35.)

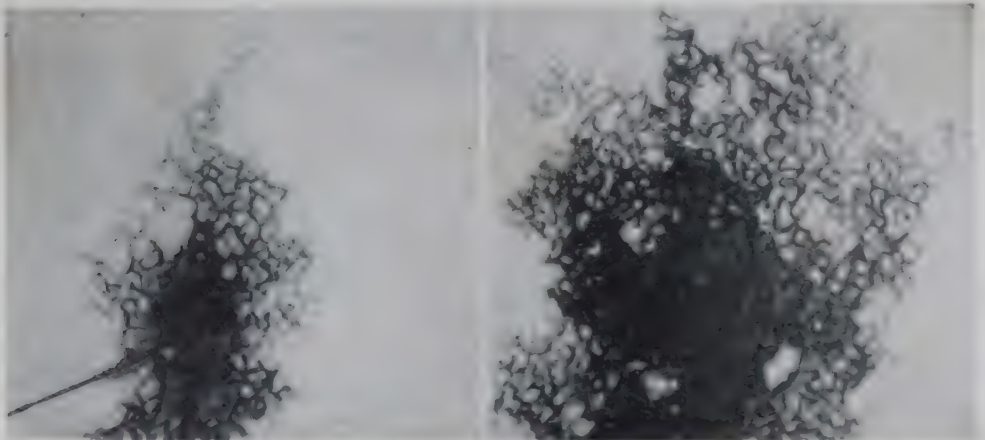


Fig. 164. Successive stages in the distribution of dye during injection of the skin with patent blue V. The photographs were selected from a moving picture film to show the course of events or further some characteristic individual differences. Magnification  $\times 32$ . (Hudack, S. S., and McMaster, P. D.: *J. Exper. Med.*, vol. 57.)

and studied. They found that injection of vital dyes into the superficial layer of the skin renders the lymph channels plainly visible. Figure 164 shows the lymphatics of the normal living skin.

## CHEMISTRY OF THE SKIN

The content of the various constituents of the skin depends to a considerable extent upon the diet of the individual.<sup>28</sup> Tissue constituents may vary considerably, whereas the blood constituents are maintained within narrow limits. Therefore the blood picture does not reflect chemical tissue constituents; e.g., there may be hyperglycoderma without hyperglycemia.<sup>29</sup>

TABLE 247  
IMPORTANT CONSTITUENTS OF SKIN  
(Urbach, 1946)<sup>28</sup>

	<i>Mg./100 ml.</i>
Water.....	610-675
Total nitrogen*.....	3500-4000
Nonprotein nitrogen.....	70-80
Amino acid nitrogen.....	17-38
Sugar.....	55-68
Total cholesterol.....	250
Cholesterol esters.....	160
Chlorides (as NaCl).....	200-320
Sodium.....	95-139
Potassium.....	60-119
Calcium.....	9-15
Magnesium.....	7-12

\* Since protein contains about 16 per cent nitrogen, it is conventional to convert the percentage of nitrogen to that of protein by multiplying by 6.25.

**HYDROGEN ION CONCENTRATION.** Table 248 gives the hydrogen ion concentration of the skin.

TABLE 248  
HYDROGEN ION CONCENTRATION OF SKIN SURFACE AND SWEAT  
(Compiled from the literature by Beerman)

<i>Method</i>	<i>Range of pH</i>
Universal indicator and capillaries.....	Face, trunk, lower extremities, hands and feet, 3.5-5.8; groin, 5.5-6.3; between toes, 5.5-6.5; armpit, 6.5-8
Vacuum tube potentiometer with glass electrode.....	100 medical students and 11 nurses, average age 19-27 years, 4-7 (mostly 4.2-5.6). Women averaged about 0.5 higher than men. Exterior surfaces of arms slightly more alkaline than corresponding flexors; antecubital region most acid area on arm
Potentiometric (glass electrode).....	3-5 different layers: keratin, 3-5; prickle cell, 6.7-6.9; basal cell, 7-7.4; cutis, 7.4-7.5
Colorimetric.....	Flexor surface of index finger, 6.3-4.7; flexor surface of forearm, 6.9-4.5; extensor surface of forearm, 6.8-4.2; axilla, 7-4.6; groin, 6.1-5; 4th interdigital space on foot, 7.7-5.7 (study based on 20 normal subjects)

**CARBOHYDRATE.** Cornbleet<sup>4</sup> found the normal skin sugar (glycogen and glucose) from fasting patients to be between 68.1 and 84.7 mg. per 100 gm. The blood values were always greater than those of the skin. The glucose concentration of the normal skin (excluding the subcutaneous fat layers) ranges between 0.2 and 81.5 mg. per 100 gm. Urbach<sup>28</sup> found higher blood and skin levels in Vienna than in Philadelphia.

FAT. Adipose tissue constitutes 18 per cent by weight of a person of average nutrition. It is subject to many physiologic variations. Wells<sup>43</sup> gives a full discussion.

TABLE 249  
NITROGEN VALUES IN SKIN  
(Urbach and Sicher, 1931)<sup>30</sup>

	Mg./100 ml.
Total nonprotein nitrogen.....	63-84
Urea nitrogen.....	6-11.5
Uric acid nitrogen.....	1- 1.3
Creatinine nitrogen.....	0.4- 0.6
Creatine nitrogen.....	1.1- 1.6
Free amino-acid nitrogen.....	17-31
Combined amino-acid nitrogen.....	20-51

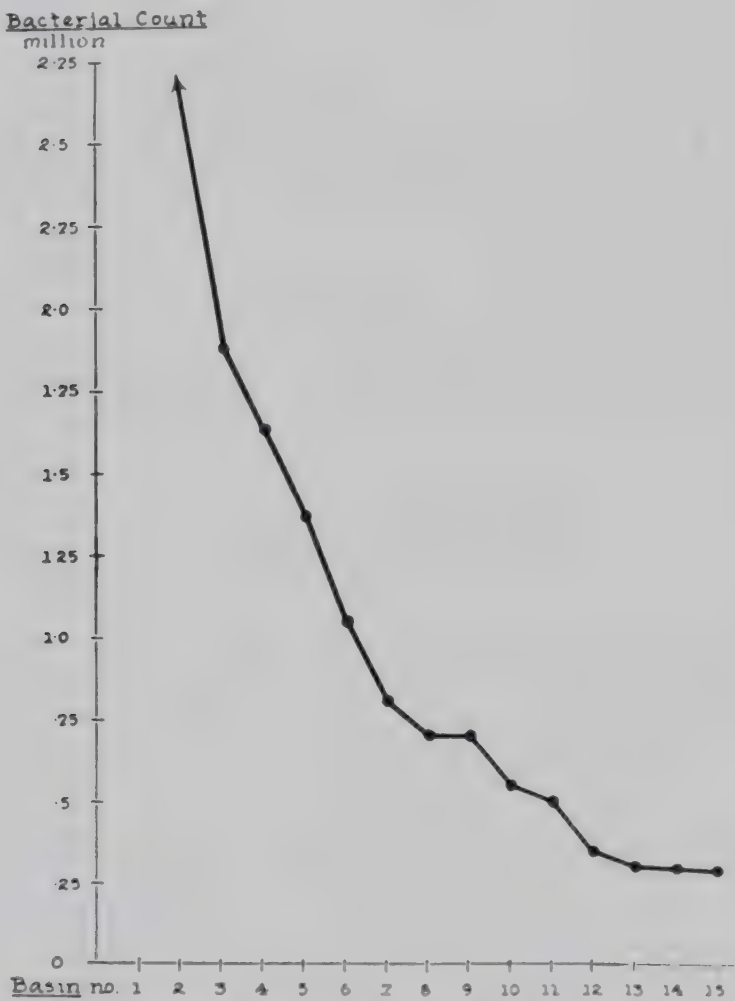


Fig. 165. The average number of bacteria removed by successive scrubblings of the hands and forearms (1.5 gm. of soap in 4.5 ml. of solution for each arm) of three subjects. (Pillsbury, D. M., Livingood, C. S., and Nichols, A. C.: Arch. Dermat. & Syph., vol. 45.)

NITROGEN. Table 249 shows the normal nitrogen content of the skin of man. The protein components are *albumin, globulin, mucin, keratin, elastin, collagen and melanin.*

Amino acid in the skin consists of *lysin, histidine, cystine, tyrosine and tryptophane.*<sup>6</sup>

## BACTERIAL FLORA OF NORMAL SKIN

The number and species of bacteria found in or on the skin depend upon environment, season and other factors. They differ on various parts of the body, the most exposed parts having the highest number.

Pillsbury and his co-workers<sup>18</sup> studied the number of bacteria removed from the hands and forearm by scrubbing with soap and water. In the initial basin they found 2,750,000 bacteria. In the first six basins the count fell rapidly; then the curve became less sharp and reached a plateau at a level somewhat above 250,000 organisms per basin (Fig. 165).

TABLE 250

PERCENTAGE INCIDENCE OF MICRO-ORGANISMS IN SCRAPINGS FROM THE SKIN AND SCALP OF 133 PATIENTS

(Downing, Nye and Cousins, 1937)<sup>5</sup>

Organism	Surface of Nose	Skin of Nose	Scalp
<i>Pityrosporum ovale</i> .....	44	24	52
<i>Corynebacterium acnes</i> .....	87	92	62
<i>Staphylococcus epidermidis</i> .....	78	76	32
Scurf <i>Staphylococcus</i> I.....	29	29	35
Scurf <i>Staphylococcus</i> II.....	4	4	23
<i>Staphylococcus epidermidis</i> var.....	7	10	6
Scurf <i>Staphylococcus</i> var.....	1	3	2
<i>Staphylococcus aureus</i> .....	3	10	6
<i>Staphylococcus albus</i> .....	6	3	3
<i>Micrococcus</i> .....	20	18	36
<i>Sarcina</i> .....	2	3	4
<i>Streptococcus</i> .....	1	1	3
Gram-negative bacilli.....	7	6	1
Gram-positive bacilli.....	8	7	3

The following micro-organisms were found in an incidence of less than 3 per cent: large diphtheroids, *Aspergillus glaucus* and *niger*, *Cryptococcus*, *Mucor*, *Mycoderma*, *Hormodendron*, *Actinomyces*, *Alternaria*, *Dermatium*.

TABLE 251

YEASTLIKE ORGANISMS RECOVERED FROM 100 NORMAL PERSONS

(Benham and Hopkins, 1933)<sup>3</sup>

Organism	Finger	Toenail	Toeweb
<i>M. parapsilosis</i> .....	1	0	1
<i>M. krusei</i> .....	1	0	0
<i>Monilia</i> , unidentified.....	2	0	1
<i>Cryptococcus</i> , group I.....	28	32	23
<i>Cryptococcus</i> , group II.....	0	3	4
<i>Cryptococcus</i> , group III.....	2	2	1
<i>Cryptococcus</i> , group IV.....	19	2	4
<i>Mycoderma</i> , group II.....	4	23	8

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## Chapter 51

### HAIR

**NUMBER OF HAIRS.** According to Pinkus,<sup>5</sup> the number of scalp hairs per square centimeter varies from 120 to 200 with no difference between blondes and brunettes. The figures given by other authorities show a difference depending upon the color of the hair. Savill<sup>7</sup> gives 1000 per square inch without reference to color.

Six to 25 per cent of all scalp hair is lanugo.

For hair counts of different regions of the body, see Tables 252 and 253.

Eyebrows have about 600 hairs each. Eyelids have 150 to 200 in the upper lid, and 75 to 100 in the lower lid.

TABLE 252

#### HAIR COUNTS

(Pinkus, 1929)<sup>5</sup>

<i>Region</i>	<i>Number per Sq. Cm.</i>
Scalp (vertex of parietal region) . . . . .	300-320
Occipital and forehead . . . . .	200-240
Chin . . . . .	44
Pubic . . . . .	30-35
Dorsum of forearm . . . . .	24
Dorsum of hand . . . . .	18

TABLE 253

#### SCALP HAIR COUNTS

(Stelwagon, cited by Savill, 1945)<sup>7</sup>

<i>Color of Hair</i>	<i>Number per Square Centimeter</i>
Blonde . . . . .	140,000
Brown . . . . .	109,000
Black . . . . .	108,000
Red . . . . .	90,000

**LENGTH.** The length of scalp hairs varies with the race, but is the same in both sexes of any race. The range is as follows:

Several millimeters to 1.5 meters<sup>3</sup>

Men: 5-12 cm.<sup>4</sup>

Women: 60-70 cm.<sup>1</sup>

Twenty to 28 inches (may go to 7-9 feet)<sup>7</sup>

The cilia of the eyelids (lashes) range up to 11 mm. in length and are rarely more, often less.

The length of axillary hair is from 4 to 8 cm. and is the same for both sexes.

THICKNESS (DIAMETER). The hairs of women are slightly thicker than those of men. Children's hair is finer than that of adults. The range is:

Fine hair, 1/1500-1/500 inch  
Coarse hair, 1/400-1/140 inch  
Women: 1/500-1/250 inch<sup>10</sup>  
Men: 1/525-1/300 inch<sup>10</sup>

TABLE 254  
THICKNESS OF HAIR  
(Pinkus, 1929)<sup>5</sup>

Region	Thickness in Microns	Investigator
Scalp Hair.....	56- 77	Oesterlen
	51- 75	Deutsche, Frederic
	47-108	Wilson
Pubic hair.....	54-135	Falck
Eyelids.....	90-120	Mably
Beard.....	102-203	Falck

RATE OF GROWTH AND LIFE SPAN. The growth cycle of hair is roughly proportionate to its thickness.<sup>9</sup> The rate of growth is 2 to 5 mm. per ten days, or  $\frac{3}{4}$  inch per month. When the hair reaches the skin level, the rate is slower. When hair is 10 to 14 inches long, the rate is still slower (Pinkus, 1882, cited by Savill<sup>7</sup>).

At the rate of 0.4 mm. a day, it takes from four to five years to attain full length (Friedenthal,<sup>2</sup> cited by Pinkus<sup>5</sup>), or 1600 days.<sup>8</sup> The rate according to Pinkus<sup>5</sup> is 0.2 mm. per day to puberty, then 0.3 to 0.5 mm. daily; 1 cm. per month or 12 cm. per year.

The life span of eyelashes from their appearance to shedding is 150 days (Donders, cited by Pinkus); 112 days (Friedenthal,<sup>2</sup> cited by Pinkus<sup>5</sup>). The hairs of the eyebrow have a life span of about 112 days.

TABLE 255  
RANGE OF VARIATION AND AVERAGE GROWTH OF HAIR (WOMEN)\*  
(Trotter, 1922)<sup>9</sup>

Region of Body	Average Increase in Mm. (Weeks)						Average Weekly Rate 6th to 11th Week
	1st	2d	3rd	4th	5th	6th	
Axilla.....	3.0	2.4	3.6	2.6	2.8	2.6	2.92
Vertex.....	3.0	2.8	2.6	2.5	3.5	2.9	2.73
Leg.....	2.2	1.8	2.4	1.4	0.7	1.3	1.62
Arm.....	1.5	2.5	2.0	1.2	1.2	0.8	1.52

\* Eight subjects studied.

COLOR. Differences in keratin, not coloring matter, are responsible for differences in the color of the hair.<sup>6</sup>

Red hair: keratin rhodokeratin  
 Black hair: keratin melanokeratin  
 Colorless hair: keratin = leukokeratin  
 Blonde, brown or black hair are mixtures of the last two

The proportion of different colors of hair is dependent upon race and age. The proportions listed in the Surgeon General's report of 100,000 demobilized American soldiers in 1919 give a fair idea relative to American men. These figures are as follows:

Number per 1000 men:

Flaxen . . . . .	46.67
Light brown . . . . .	222.77
Medium brown . . . . .	212.57
Dark brown . . . . .	460.69
Char red . . . . .	12.66
Red and black (glossy black) . . . . .	44.64

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Chapter 52

SUDORIPAROUS GLANDS

NUMBER. The total number of sudoriporous glands in the human body is estimated at 2.38 million.<sup>11</sup> There are two types: the *apocrine* and the *eccrine*. The apocrine are more numerous in women and in Negroes. Comparison of the apocrine and eccrine glands is made in Table 256. They are located over the entire body, but are unevenly distributed. Thin epidermis contains 120 glands per square inch, and thick epidermis 371 glands per square inch.<sup>17</sup> The eccrine glands per square inch in various parts of the body, according to Krause,<sup>1</sup> are as follows:

Soles.....	2700
Palms.....	2700
Dorsum of hand.....	1500
Thorax, abdomen, arms.....	1100
Dorsum of foot.....	900
Cheeks and thighs.....	500-600
Posterior surface of neck, back and buttocks.....	400-600

TABLE 256

APOCRINE AND ECCRINE GLANDS COMPARED ANATOMICALLY AND OTHERWISE  
(Way and Memmesheimer, 1938)<sup>25</sup>

	<i>Eccrine Glands</i>	<i>Apocrine Glands</i>
Origin.....	Undifferentiated epithelium	Differentiated epithelium
Time of development.....	Before birth	At puberty
Number present.....	Many	Few
Location.....	Generalized, except anterior surfaces of nails, labia minora, inferior parts of labia majora, inner surfaces of prepuce, glans and internal part of pinna of ear	Axilla, anus, mons veneris, breast and abdomen
Size of ducts.....	Small	Large
Secretion.....	More fluid	Less fluid
Secretion without loss of substance from secreting cells.....	Yes	No
Stain deeply with hematoxylin.....	Yes	No
Strong, muscular layer surrounding epithelial cells.....	No	Yes
Iron in secreting cells.....	No	Yes
Glands more coiled and narrower at distal end.....	Yes	No
Usually connected with hair follicle.....	No	Yes
Open directly on surface of skin.....	Yes	No
Size.....	Small	Large
Chemical reaction of sweat.....	pH 3.8-5.6	pH 6.2-6.9

SIZE. Sweat glands measure from 1 to 4 mm. or more in diameter. The nipple glands, especially during pregnancy, are the largest.

TABLE 257

DISTRIBUTION OF FUNCTIONAL SWEAT GLANDS ON DIFFERENT BODY SURFACES (FUNCTIONAL PORES PER SQUARE CENTIMETER)  
(Randall, 1946)<sup>16</sup>

Area	Subject				
	1	2	3	4	5
Forearm, extensor surface	252	180	195	...	225
Upper arm, over biceps	220	140	...	...	170
Dorsum of hand	410	260	480	416	320
Trunk, anterior chest	175	93	...	...	184
Scapular region of back	...	28	44	29	17
Leg, over gastrocnemius	116	85	...	63	130
Thenar eminence	368	264	440	146	200
Face, forehead	212	37(?)	...	...	122
Zygomatic	14	1	7	65	20
Buccal	34	9	...	...	6

Mecholyl was used to stimulate activity in all regions except the thenar eminence in subject 1. The question in Subject 2 indicates a probable inhibition of sweating by mecholyl antophoresis.

SWEAT (PERSPIRATION)

Normally, perspiration or sweat is present at all times. When it is not noticeable it is called *insensible perspiration*. Insensible perspiration is affected by: (1) environmental temperature, (2) relative humidity, (3) ventilation and clothing, (4) food intake, (5) water intake, (6) muscular exercise and (7) blood circulation and skin temperature.

Insensible perspiration is fairly uniform over the body except the palms and soles, where it is five to ten times as great<sup>2</sup> (Figs. 166 and 167).

Palmar sweat glands secrete in groups every twelve to thirty seconds. Each individual gland discharges 0.003 to 0.0005 mg. of sweat.<sup>13</sup>

In a normal-sized, afebrile adult the insensible perspiration amounts to between 800 and 1200 ml. per day. It varies between 0.557 and 1.762 gm. in a one-half hour.<sup>8, 14</sup>

Under the influence of heat, exercise or disease the quantity of sweat may be greater than 2 liters in twenty-four hours.<sup>25</sup> In the tropics and hot deserts sweat production may amount to 5 to 12 liters per day.<sup>5, 6</sup>

CHEMISTRY OF HUMAN SWEAT. Besides the minerals, sweat contains *urea*, *lactic acid*, *amino acids*, *ammonium*, *sugar* and *lactic acid*. Factors which affect the blood composition also cause alteration in sweat. Considerable differences in the mineral composition of sweat are reported, but regardless of its variations it is always hypotonic.<sup>22</sup>

The bromide concentration of unfiltered sweat of normal subjects is 18.2 to 50.2 micrograms per 100 ml., and filtered sweat 16.5 to 41.2 micrograms.<sup>3</sup>

Sulfonamides are present after administration.<sup>1, 3, 10</sup>

Immune substances may be present in sweat.  
Bismuth is not excreted even by persons under treatment for syphilis.  
HYDROGEN ION CONCENTRATION. The pH of sweat ranges from 5.2 to 6.75.

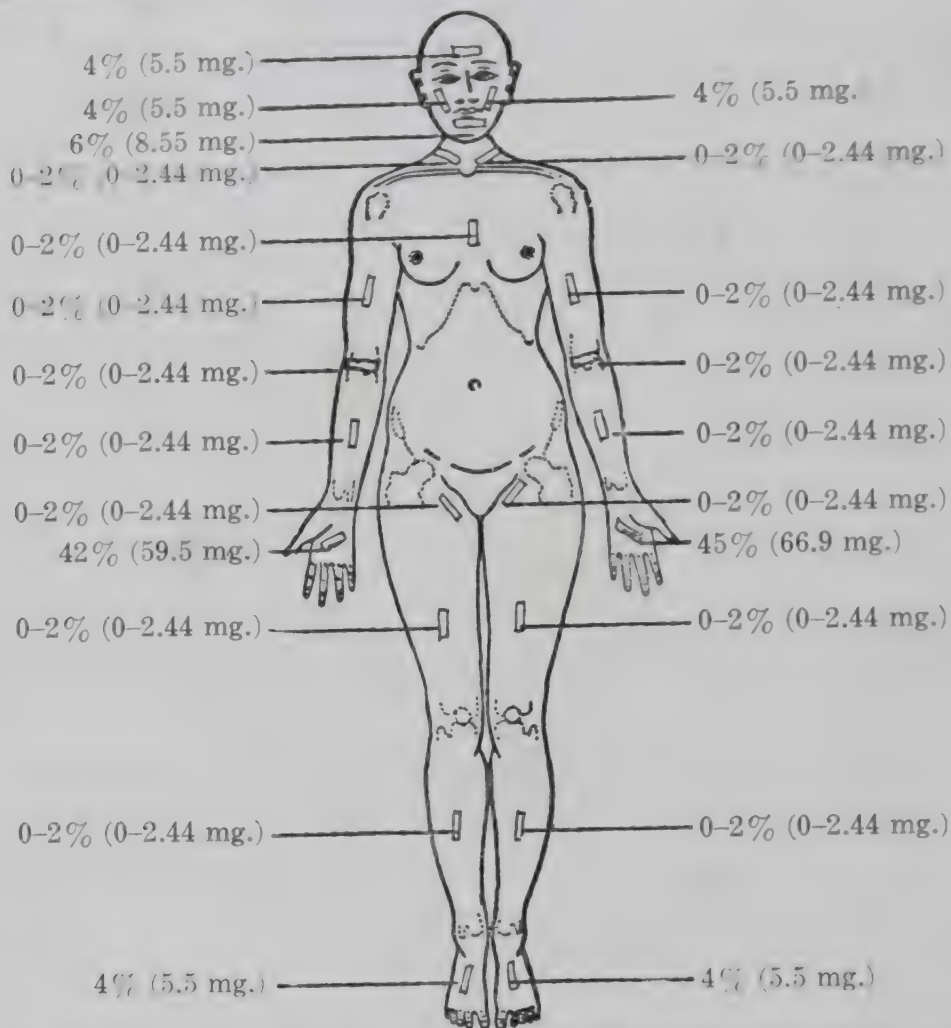


Fig. 166. Average readings of insensible perspiration derived from a study of 22 normals —anterior surfaces. Readings were made on subjects under basal conditions. The patches were read after having been exposed to the skin for 15 minutes. The “test patch” readings are indicated as the highest per cent cobaltous chloride drop which changed from blue to pink. The numbers in the brackets express these readings converted to milligrams of water per square centimeter of body surface per hour. (Fowle, L. P., Legault, R. R., Delluva, A., and Georg, L.: J. Invest. Dermat., vol. 5.)

TABLE 258  
AVERAGE COMPOSITION OF SWEAT  
(Schwartz and Peck, 1946)<sup>20</sup>

	Percentage
Water.....	99.02
Propionic acid.....	0.0062
Acetic acid.....	0.0096
Caprylic, and caproic acid.....	0.0046
Sodium chloride.....	0.7
Lactic acid.....	0.1
Citric acid.....	0.004
Ascorbic acid.....	0.004
Urea.....	Trace
Uric acid.....	Trace

**ANDROGENIC SUBSTANCES.** These are not present in sweat even after intramuscular injection of large amounts of testosterone propionate.<sup>3</sup> Gilman and Veidman<sup>4</sup> obtained negative Aschheim-Zondek tests in the sweat of pregnant women.

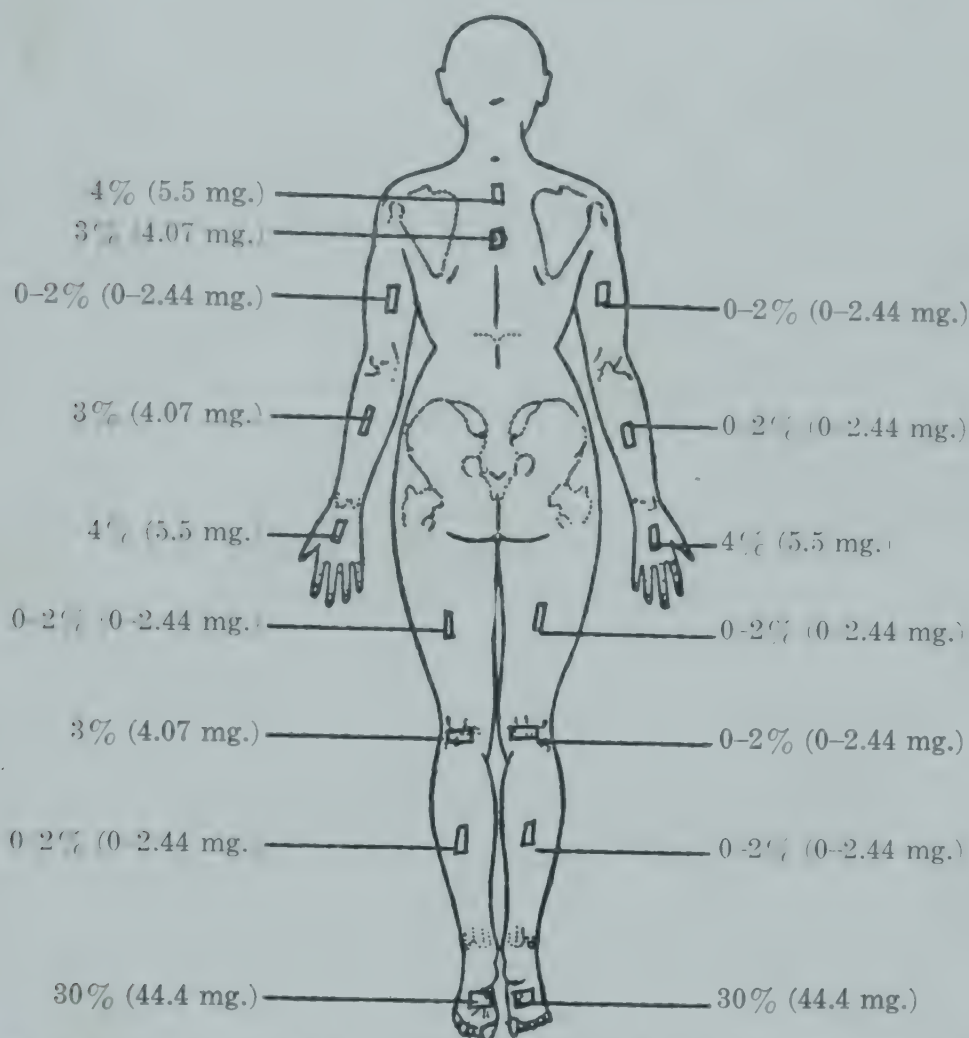


Fig. 167. Average readings of insensible perspiration derived from a study of 22 normals on posterior surfaces. (Fowle, L. P., Legault, R. R., Delluva, A., and Georg, L.: *J. Invest. Dermat.*, vol. 5.)

## SEBACEOUS GLANDS

These glands first appear in the skin of the scalp at 4.5 months of fetal life, and on the labia minora at two to four months of extra-uterine life (Kolliker, quoted by Way<sup>24</sup>). They accompany the hairs, but occur independently at the border of the vermilion of the lips, labia minora glands, penis and prepuce, but are absent on the glands and prepuce of the clitoris. Nine-tenths of these glands open into the cavity of a hair follicle. They are sometimes present in the mouth, an anomaly called Fordyce's disease.

**SIZE OF COMPOUND GLANDS.** They range in size from 500 microns to 2 mm. Each acinus is 200 to 400 microns long.<sup>24</sup> The largest are found on the nose.

**SEBUM.** The secretion of sebum is not continuous, but stops when the cutaneous surface has reached a certain saturation of sebum. Secretion recurs when the sebum is removed by washing or other procedures.<sup>21</sup>

The velocity of sebum secretion is from 0.32 to 1.52 mg. per 48 square centimeters in fifteen minutes (the time required to reach the saturation value after complete removal of sebum).

With immediate removal of the sebum and with a constant tendency to restore sebum equilibrium, the theoretical maximum sebum secretion per day would be 125 to 180 gm. The average amount according to Kuznitsky<sup>12</sup> about 1 to 2 gm. per day (less in cold weather and in children).

Certain local and systemic factors have been investigated for their relation to the secretory activity of the sebaceous glands. Stein<sup>23</sup> associated sebum secretion in an interesting manner with age and sex gland activity. He ascribed the formation of the fetal vernix caseosa to stimulation by hormonal substances from the mother. After birth the infant's sebaceous glands become relatively inactive, to assume greater importance only at the time of puberty, for then the hormonal stimulus sets in once again. During the onset of senility there is a period when the sebum secretion is markedly enhanced. This occurs shortly before the senile shrinkage of the gland.

**CHEMICAL COMPOSITION.** According to Schmidt,<sup>19</sup> quoting Porier and Sharpy,<sup>15</sup> the chemical analysis of sebum is as follows: *water*, 31.7 per cent; *epithelium and protein matter*, 61.75 per cent; *fat*, 4.16; *butyric, valeric and caproic acid*, 1.21 per cent; *ash*, 1.18 per cent.

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## Chapter 53

### FINGERNAILS AND TOENAILS

**RATE OF GROWTH.** It takes 130 to 160 days for the nail to grow from the matrix to the free edge. Growth is faster in fingers than in toes, faster in summer than in winter, and faster in children.<sup>4</sup>

It takes 180 days for nails to grow from the lunula to the free edge, according to Schwartz and Peck.<sup>2</sup> Clark and Buxton<sup>1</sup> give the growth rate as 3 mm. in one month (faster in nail biters). It varies with fingers; in the third digit

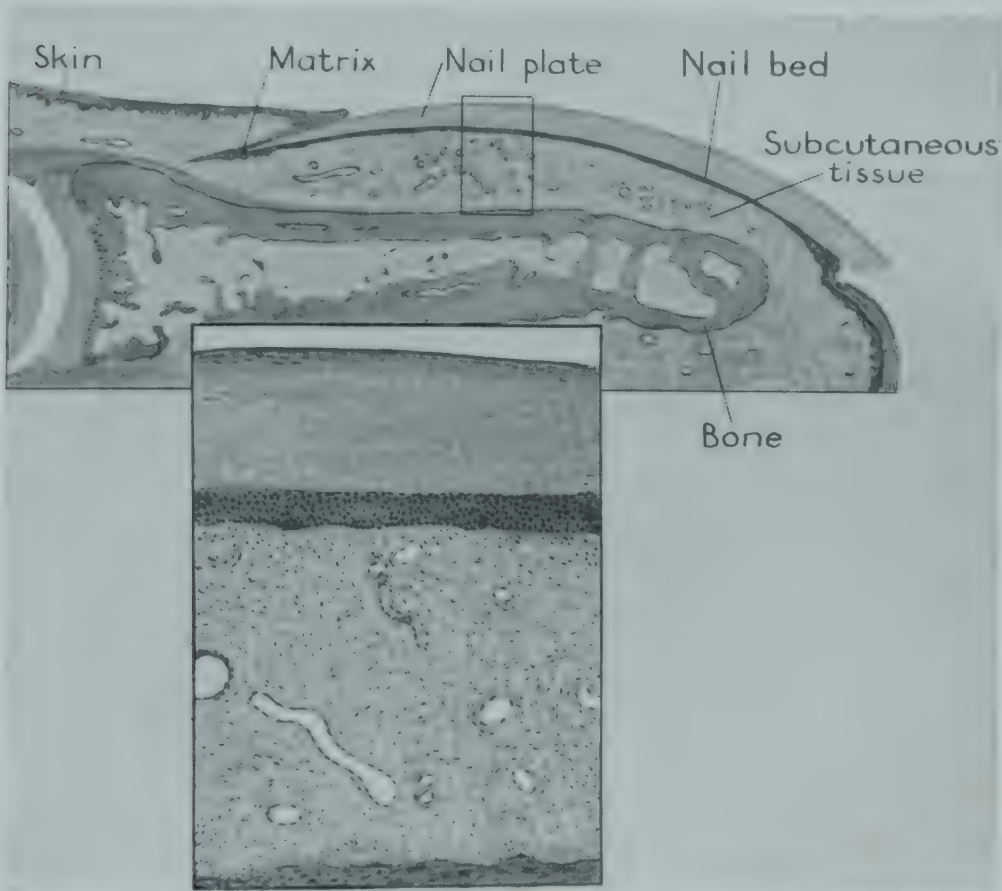


Fig. 168. Longitudinal section of the fingernail. (Silver, H., and Chiego, B.: *J. Invest. Dermat.*, vol. 3.)

ail it is greater. The thumbnail grows slightly less rapidly than the nails of the index and ring fingers. Between ten and twenty-three years of age there is no variation of nail growth. In early infancy nail growth is slow, and at the age of three years it approximates the adult standard.

There are no sexual differences and no differences between the right and left hands.

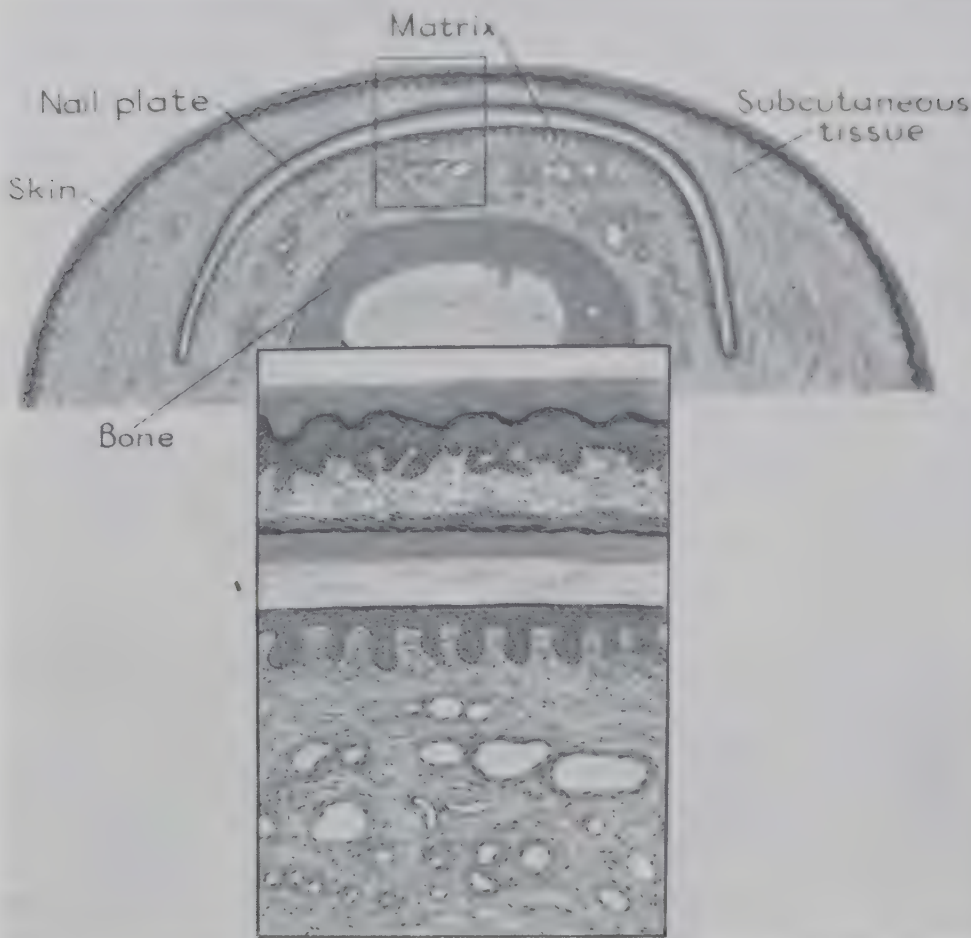


Fig. 169. Cross section of the fingernail. (Silver, H., and Chiego, B.: J. Invest. Dermat., vol. 3.)

TABLE 259  
CHEMISTRY OF THE NAILS  
(Adapted from Silver and Chiego, 1940)<sup>3</sup>

Average Analysis per Cent	
Keratins.....	Carbon, 48.7 Hydrogen, 6.59 Nitrogen, 16.55 Sulfur, 3.92 Cystine, 2.31 Histidine, 0.59 Lysine, 3.08 Arginine, 10.01
Sulfur.....	Fingernail, average 3.2 up to 5 (as cystine)
Fat.....	0.15-0.75 (keratin) 1.38, fingernails of children
Moisture.....	7-12
Ash.....	0.042 (sodium, calcium, potassium, magnesium and iron, present as chlorides, sulfates, phosphates and carbonates)

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Section XII

THE EYE

(Normal Values in Ophthalmology)



## Chapter 54

### THE EYE

**DIMENSIONS.** The dimensions of the globe are relatively constant, varying only within a millimeter or so. The measurements of the normal eye are as follows:

Average diameters:

Sagittal, outer.....	24-26 mm.
inner.....	21.74-22.5 mm.
Transverse.....	23.32-24.27 mm.
Vertical.....	23-23.7 mm.
Circumference.....	72.2-77.62 mm.

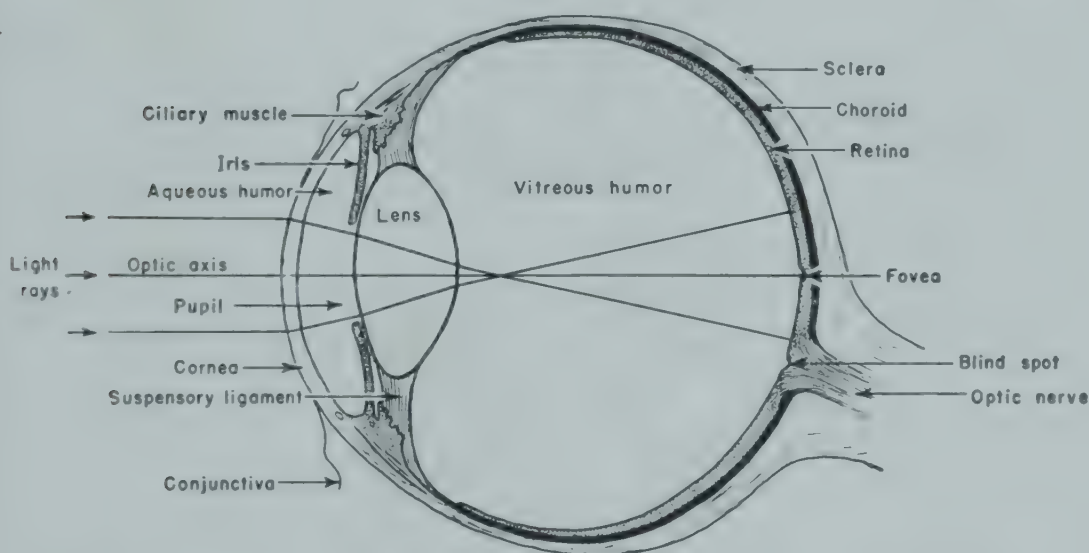


Fig. 170. Cross section of human eye. (Hunter and Hunter, College Zoology.)

The diameters of the eye of the newborn are: sagittal, 17.3 mm.; equatorial, 16 mm.; vertical, 15.4 mm.<sup>14</sup>

### VISUAL ACUITY

Visual acuity ( $V$ ) is expressed as a fraction, the denominator ( $D$ ) being a letter equal in height and width to a perpendicular which will subtend an angle of 5 minutes at a distance of 6 meters or 20 feet. The numerator ( $d$ ) is the distance of the patient from the test object. This can be expressed as

$$V \text{ (vision)} = \frac{d}{D}$$

The average visual acuity is 20/20 when expressed in units of feet and 6/6 in units of meters. Visual acuity of 20/40 or better is considered satisfactory

by most of the State Workmen's Compensation Boards. The normal range of visual acuity is usually considered to be from 20/15 to 20/40.

Table 265 shows the rate of change of visual acuity relative to age.

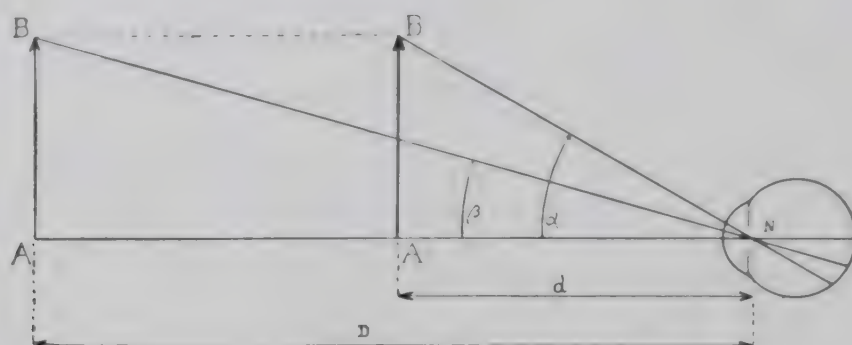


Fig. 171. Graphic explanation of the equation  $V = \frac{d}{D}$ . (Berens.)



Fig. 172. Snellen's test types. (Berens.)

Table 262 shows the relation between visual acuity and *visual efficiency*.

The International Congress of 1909 introduced decimal fractions in the notation of visual acuity, the range of fraction being from 0.1 to 2.0. The

International test types are arranged in twelve rows: the first represents a visual acuity of 0.1, the second, 0.2, and increasing to 1.0. There are also tests for visual acuity of 1.5 to 2.0 (see Table 261).

TEST CHART--A.M.A. RATING

1.0 or 20/20	20.0 FT.	100%
L T V U P R H Z C F D N C		
0.83 or 20/25.7		95%
F D N E C H B S C Y R L		
0.62 or 20/32.1		90%
T Y O D Z E C H B P		
0.52 or 20/38.4		85%
U P N E S R D H		
0.44 or 20/44.9		80%
C V O F E H S		
0.38 or 20/52.1		75%
O C L C T R		
0.33 or 20/60.3		70%
N R T S Y F		
0.29 or 20/68.2		65%
E O B C D		
0.26 or 20/77.5		60%
U F V P		
0.23 or 20/86.8		55%
H T S C		
0.20 or 20/97.5		50%
P E R		

TEST CHART--A.M.A. RATING

0.19 or 20/109.4		45%
D B C		
0.16 or 20/122.5		40%
Y L V		
0.14 or 20/137.5		35%
F P		
0.13 or 20/155		30%
N Z		
0.11 or 20/175		25%
O C		
0.10 or 20/200		20%
H E		

FOR MEASUREMENT OF VISION BETWEEN 20/200 AND 20/400. REDUCE DISTANCE BETWEEN PATIENT AND CHART TO 10 FEET, AND REDUCE NOTATION OF VISUAL ACUITY CORRESPONDINGLY.

Fig. 173. The far test type chart, adopted by the American Medical Association, 1940, for the percentage rating of visual acuity. (Berens.)

The percentage rating of visual acuity may be determined by the far and near test type charts adopted by the American Medical Association in 1932 (Figs. 172 and 173).

TABLE 260  
VISUAL EFFICIENCY RATINGS (EVANS)  
(Berens, 1936)<sup>1</sup>

<i>American Medical Association Percentage Equivalents of Visual Efficiency* (Far Types)</i>					<i>New York State Compensation Commission Ratings†</i>	
International Decimal System	French Metric Fractions	English Fraction in Feet	Efficiency	Loss	Efficiency	Loss
1.01.....	6/ 6.09	20/ 20	100.0	0.0	100.0	0 0
1.52.....	6/ 9.13	20/ 30	91.5	8.5	66.0	33 0
2.06.....	6/12.24	20/ 40	83.6	16.4	50.0	50 0
2.56.....	6/15.24	20/ 50	76.5	23.5	40.0	60 0
3.55.....	6/21.33	20/ 70	64.0	36.0	28.56	71 44
5.08.....	6/30.48	20/100	48.09	51.1	20.0	80 0
10.16.....	6/60.96	20/200	20.0	80.0		

\* To July, 1933, used by ten states and favored by eight large insurance companies.

† As of 1933. The English fraction in feet, reduced directly to a decimal, when the loss is 80 per cent, is considered as 100 per cent industrial loss (total blindness).

TABLE 261  
VISUAL ACUITY EQUIVALENTS (FAR TYPES\*)  
(Berens, 1936)<sup>1</sup>

<i>Size of Letter†</i>	<i>Size of Limb‡</i>	<i>Size of Letter‡</i>	<i>Size of Limb‡</i>	<i>International Decimal System</i>	<i>French Metric Fractions</i>	<i>English Fraction in Feet</i>
8.86.....	1.77	0.348	0.069	1.01	6/ 6.09	20/ 20
12.27.....	2.65	0.483	0.104	1.52	6/ 9.13	20/ 30
17.79.....	3.56	0.700	0.140	2.06	6/12.24	20/ 40
22.15.....	4.43	0.872	0.174	2.56	6/15.24	20/ 50
31.11.....	6.20	1.224	0.244	3.55	6/21.33	20/ 70
44.31.....	8.86	1.744	0.348	5.08	6/30.48	20/100
88.63.....	17.73	3.489	0.698	10.16	6/60.96	20/200

\* These figures represent only the Snellen interval. The interval of Green should be considered by anyone devising new test charts.

† Measured in millimeters.

‡ Measured in inches.

TABLE 262  
RELATION BETWEEN VISUAL ACUITY AND VISUAL EFFICIENCY  
(Sterling and Snell, 1926)<sup>12</sup>

<i>Snellen Notation</i>	<i>Visual Angle in Minutes</i>	<i>Visual Efficiency in per Cent</i>	<i>Percentage Loss of Vision</i>
0/20.....	1.0	100.0	0
0/25.....	1.25	95.6	4.4
0/30.....	1.50	91.4	8.6
0/40.....	2	83.6	16.4
0/50.....	2.25	76.5	23.5
0/60.....	3	69.9	30.1
0/70.....	3.5	63.8	36.2
0/80.....	4	58.5	41.5
0/90.....	4.5	53.4	46.4
0/100.....	5	48.9	51.1
0/120.....	6	40.9	59.1
0/140.....	7	34.2	65.8
0/160.....	8	28.6	71.4
0/180.....	9	23.9	76.1
0/200.....	10	20.0	80.0
0/220.....	11	16.7	83.3
0/240.....	12	14.0	86.0
0/260.....	13	11.7	87.3
0/280.....	14	9.8	90.2
0/300.....	15	8.2	91.8
0/340.....	17	5.7	94.3
0/380.....	19	4.0	96.0
0/400.....	20	3.3	96.7
0/500.....	25	1.1	98.9
0/600.....	30	0.6	99.4
0/800.....	40	0.1	99.9

The visual efficiency of an eye is defined as the ratio of its resolving power to the resolving power of the normal eye.

NEAR VISION. Near vision and the ability to read at near vision (within arm's length) is determined by means of a test object placed at a distance of 33 cm. from the eyes. The ability to read letters at this distance, such as those of Jaeger's type No. 1, represents the normal. In 1932 the American Medical Association adopted a near test type card (see Fig. 174). When this card is held at

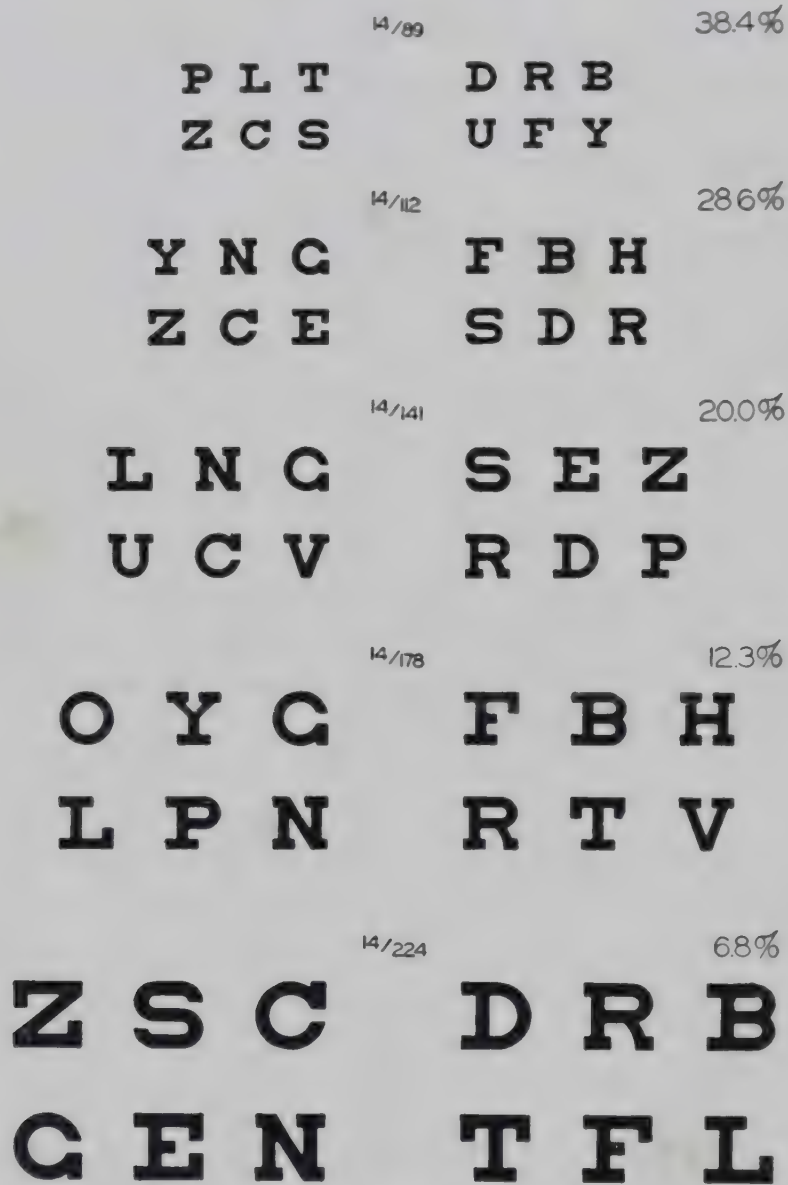


Fig. 174. The near test type card, adopted by the American Medical Association, 1940, for the percentage rating of visual acuity. The chart should be held 14 inches from the eye. The central figures designate visual acuity. Visual efficiency percentages are at the right. Berens.

a distance of 14 inches from the eyes, both visual acuity and percentage of visual efficiency can be determined. These values will depend upon the size of the test type that can be read.

VISUAL ACUITY IN INFANTS AND CHILDREN. Table 263 shows the response of infants and young children to visual tests. Table 264 shows the visual acuity of children of different ages. Table 265 shows Collins and Britton's study of

## A. M. A. RATING READING CARD

14:56		58.5%	
CLUB	EVEN	PEER	BUSH
FOOT	TROT	SHOO	LEND
POSE	ROLL	VOTE	NOUN

CHART TO BE HELD 14 INCHES FROM EYE,  
VISUAL ACUITY NOTATION IN CENTER  
VISUAL EFFICIENCY PERCENTAGE AT RIGHT.

Fig. 175. American Medical Association rating reading card, 1940. The chart is to be held 4 inches from the eye. Visual acuity notation is in the center. Visual efficiency percentage is at the right. (Berens.)

862 white school boys, giving the specified vision for each age group. Table 66 shows the percentage of boys and girls who are myopic, emmetropic or hyperopic, as determined by retinoscopic examination.

TABLE 263  
RESPONSE TO VISUAL TESTS FOR INFANTS  
(Evans, 1946)<sup>8</sup>

Age	Stimulus	Nature of Response	Responding Percentage	Assumption	Remarks	Investigator
Term*...	Intrusive reflex	Aimless wandering	100		Movements not greater than 35°. Horizontal only. Not continuous. No family history of squint	Chavasse
First 10 mins...	Flashlight	Lid reflex	100	Retina functioning	Pupils react. About 1 per 1000 have brown iris irrespective of color or race	Neur. Inst.
During first 10 days...	Flashlight	Transient convergence reflex	9	Macula begins to function	Same as above	Neur. Inst.
5-6 weeks...	Flashlight or massive objects	Follows movements with eyes for few seconds	100 ?	Developing macula function and muscle coordination	Approach of nurse or mother more frequently noted	Chavasse
6-8 weeks...	Smaller objects	Follows movements for few seconds	100 ?	Same as above		Chavasse
3-4 mos....	1" black cube against white surface at 2'	Follows movements for ½ minute	100 ?	Visual acuity 6/728.00	Head moves. Also inspects own hands. Crude as an actual measurement	Chavasse
6 mos....	½" black cube against white surface at 2'	Follows movements through full angle of eye movements	100 ?	Visual acuity about 6/288.00	Method of testing can be improved. Has perceived red and yellow for about three months	Chavasse; Duke-Elder
9 mos. to 1 yr..	Black cubes on white	Follows with eyes. Hands and body in prolonged attention	100 ?	Development and coordination of all eye functions. Visual acuity about 6/72		Chavasse
2 yrs .....	E chart	Indicating position of letter	100 ?†	6/12		Chavasse
3 yrs .....	E chart	Indicating position of letter	100 ?†	6/12		Chavasse
4 yrs .....	E chart	Indicating position of letter	100 ?	6/9		Chavasse
? yrs .....	E chart	Indicating position of letter	100 ?	6/6		Chavasse
? yrs .....	Snellen	Reads	100 ?	6/6	From this point on less liable to develop strabismus	Chavasse

\* It has been pointed out that if a powerful light be flashed on the abdominal wall of a pregnant woman shortly before term, fetal movements will become more active. This, of course, may not be an ocular response.  
† Only 50 percent of children two years of age will respond according to Evans.  
? Percentage questioned.

TABLE 264  
VISUAL ACUITY OF CHILDREN OF DIFFERENT AGES (EVANS)  
(Berens, 1936)<sup>1</sup>

At 3- 4 years	16% have 20/20 vision
At 4- 5 years	23% have 20/20 vision
At 5- 6 years	38% have 20/20 vision
At 6    years	58% have 20/20 vision
At 6- 7 years	52% have 20/20 vision
At 8- 9 years	56% have 20/20 vision
At 10-11 years	61% have 20/20 vision
At 12-13 years	70% have 20/20 vision
At 14 years and over	75% have 20/20 vision

TABLE 265

PERCENTAGE OF PERSONS OF EACH AGE GROUP WITH THE SPECIFIED VISION AS DETERMINED BY THE SNELLEN TEST\*

(Collins and Britton, 1924)<sup>5</sup>

Age—Years	Percentage			Number of Persons			
	Normal in Both Eyes ( $\frac{20}{20}$ or Better)	$\frac{20}{40}$ or $\frac{20}{30}$ in One Eye and $\frac{20}{20}$ or Better in Other	$\frac{20}{50}$ or Less in One or Both Eyes	Total Exam- ined	Normal in Both Eyes ( $\frac{20}{20}$ or Better)	$\frac{20}{40}$ or $\frac{20}{30}$ in One Eye and ( $\frac{20}{40}$ or Better) in Other	$\frac{20}{50}$ or Less in One or Both Eyes
School children:							
6.....	57.1	38.5	4.4	205	117	79	9
7.....	60.2	34.1	5.7	492	296	168	28
8.....	61.2	35.4	3.4	590	361	209	20
9.....	62.4	32.8	4.8	631	394	207	30
10.....	65.3	26.5	8.2	683	446	181	56
11.....	65.5	28.5	6.0	568	372	162	34
12.....	71.3	22.3	6.4	533	380	119	34
13.....	68.5	23.2	8.3	444	304	103	37
14.....	72.6	21.2	6.2	339	246	72	21
15.....	66.3	24.9	8.8	193	128	48	17
16.....	70.8	18.8	10.4	96	68	18	10
17 and over.....	72.7	20.5	6.8	88	64	18	6
Industrial workers:							
Under 20.....	77.2	13.8	9.0	356	275	49	32
20 to 24.....	67.7	22.7	9.6	896	607	203	86
25 to 29.....	61.3	27.3	11.4	1137	697	310	130
30 to 34.....	60.1	27.8	12.1	1078	648	300	130
35 to 39.....	54.8	29.4	15.7	1023	561	301	161
40 to 44.....	49.5	35.5	15.0	715	354	254	107
45 to 49.....	34.6	40.2	25.2	572	198	230	144
50 to 54.....	22.6	38.1	39.3	341	77	130	134
55 to 59.....	17.9	30.1	52.0	196	35	59	102
60 and over.....	5.5	26.7	67.9	165	9	44	112

\* Four thousand eight hundred and sixty-two native white school boys and 6479 male white industrial workers in various localities in the United States.

TABLE 266

AGE PREVALENCE OF VARIOUS TYPES OF REFRACTIVE ERRORS AS DETERMINED BY RETINOS-  
COPIC EXAMINATION AFTER THE ADMINISTRATION OF A CYCLOPLEGIC

(Kempf, Collins and Jarman, 1928)<sup>10</sup>

Right Eye

Age Last Birthday	Total Hyper- opia <sup>1</sup>	Total My- opia <sup>2</sup>	Total Astig- ma- tism <sup>3</sup>	Em- me- tropia	Hy- per- opia	Simple Hyper- opic Astig- ma- tism	Com- pound Hyper- opic Astig- ma- tism	Mixed Astig- ma- tism	Com- pound My- opic Astig- ma- tism	Simple My- opic Astig- ma- tism	Myopia	Total Num- ber of Chil- dren
Percentage of Children												
All ages	88.3	6.9	27.7	3.4	63.4	2.7	22.2	1.4	0.9	0.5	5.5	100.0
6-7.....	94.6	1.4	19.7	1.8	77.1	.7	16.8	2.2	...	...	1.4	100.0
8-9.....	94.2	4.2	27.6	.3	68.7	3.4	22.1	1.3	.3	.5	3.4	100.0
10-11.....	86.2	8.5	32.4	2.1	59.0	2.7	24.5	3.2	.5	1.6	6.4	100.0
12-13.....	85.6	9.1	28.2	4.5	59.9	2.8	22.9	.9	1.5	.1	7.4	100.0
14 and over.	82.9	9.1	30.6	7.1	55.6	3.2	24.1	.9	1.5	.9	6.8	100.0
Number of Children												
All ages	1642	128	515	64	1179	50	413	26	17	9	102	1860
6-7.....	264	4	55	5	215	2	47	6	...	...	4	279
8-9.....	358	16	105	1	261	13	84	5	1	2	13	380
10-11.....	162	16	61	4	111	5	46	6	1	3	12	188
12-13.....	576	61	190	30	403	19	154	6	10	1	50	673
14 and over.	282	31	104	24	189	11	82	3	5	3	23	340

<sup>1</sup> Including hyperopic astigmatism.  
<sup>2</sup> Including myopic astigmatism.  
<sup>3</sup> Including hyperopic, myopic and mixed astigmatism.  
\* White school children in Washington, D. C.

ACCOMMODATION

Accommodation is that function of the eye related particularly to the ciliary muscle and lens, whereby objects at different distances may be clearly seen. In a state of rest the dioptric system of the eye presents its minimum of refractive power; the eye being adapted to the most distant point, it can see distinctly (*punctum remotum*). During a condition of greatest possible accom-  
modation the dioptric eye is adapted to its nearest point for distinct vision, (the near point or *punctum proximum*).

The total accommodative power which an eye has is represented by the difference between its refraction at rest and the refraction under its maximum effort of accommodation. This is the *power* or *amplitude of accommodation*, sometimes called the *range of accommodation*. The power of accommodation decreases with age (see Table 267).

TABLE 267

## TABLE OF NORMAL ACCOMMODATION AT VARIOUS AGES

Near Point Reckoned from Anterior Focus of Eye, i.e., 14 mm. in Front of Cornea

(Duane, 1925)<sup>6</sup>

Age (Years)	Accommodation (Diopters)		Age	Accommodation (Diopters)	
	Minimum	Maximum		Minimum	Maximum
8 .....	11.6	16.1	40 .....	3.4	7.9
9 .....	11.4	15.9	41 .....	3	7.5
10 .....	11.1	15.7	42 .....	2.7	7.1
11 .....	10.9	15.5	43 .....	2.3	6.7
12 .....	10.7	15.2	44 .....	2.1	6.3
13 .....	10.5	15	45 .....	1.9	5.9
14 .....	10.3	14.8	46 .....	1.7	5.5
15 .....	10.1	14.5	47 .....	1.4	5
16 .....	9.8	14.3	48 .....	1.2	4.5
17 .....	9.6	14.1	49 .....	1.1	4
18 .....	9.4	13.9	50 .....	1	3.2
19 .....	9.2	13.6	51 .....	0.9	2.6
20 .....	8.9	13.4	52 .....	0.9	2.2
21 .....	8.7	13.1	53 .....	0.9	2.1
22 .....	8.5	12.9	54 .....	0.8	2
23 .....	8.3	12.6	55 .....	0.8	1.9
24 .....	8	12.4	56 .....	0.8	1.8
25 .....	7.8	12.2	57 .....	0.8	1.8
26 .....	7.5	11.9	58 .....	0.7	1.8
27 .....	7.2	11.6	59 .....	0.7	1.7
28 .....	7	11.3	60 .....	0.7	1.7
29 .....	6.8	11	61 .....	0.6	1.7
30 .....	6.5	10.8	62 .....	0.6	1.6
31 .....	6.2	10.5	63 .....	0.6	1.6
32 .....	6	10.2	64 .....	0.6	1.6
33 .....	5.8	9.8	to		
34 .....	5.5	9.5	72		
35 .....	5.2	9.3			
36 .....	4.9	9			
37 .....	4.5	8.8			
38 .....	4.1	8.5			
39 .....	3.7	8.2			

## INTRA-OCULAR PRESSURE OR TENSION

The limits of normal intra-ocular pressure, measured tonometrically, usually lie between 12 and 25 mm. of mercury when using the Schiötz tonometer (see Table 268). The lower limit is fairly well fixed and does not vary

greatly, but the upper limit is a factor of the individual eye. For some eyes 23 mm. of mercury is a pathological tension. Others can withstand pressures of from 35 to 38 mm. for many years without any detectable injury.

According to Duke-Elder, 25 mm. with the Schiötz tonometer is equal to 40 mm. with the McLean tonometer.

TABLE 268  
INTRA-OCULAR PRESSURE IN NORMAL EYES ESTIMATED BY THE TONOMETER  
(Berens, 1936)<sup>1</sup>

Year	Examiner	Number of Eyes Examined	Lower Limits in Mm. Hg	Upper Limits in Mm. Hg
1908.....	Schiötz	....	19	30
1910.....	Langenhan	60	22	32
1910.....	Marple	94	19	29
1910.....	Ruata	....	19	25
1910.....	Stock	100	15.5	31 (32)
1910.....	Wegner	100	17	35
1911.....	Bietti	....	17	32
1911.....	Heilbrun	64	15.5	32
1911.....	Oeding	....	17	34
1912.....	Lübs	....	17.5	30.5
1912.....	Toczyski	30	15.5	30
1915.....	Pissarello	30	13	35
1916.....	Hine	26	24	34.5
1917.....	Cridland	1001	16	28
1917.....	Elschnig	....	19	25
1918.....	Bader	160	16	28
1921.....	Gjessing	2180	13	35
1928.....	Andrezen	447	12	35

MUSCLE BALANCE

The maintenance of single vision in the two-eyed human being depends upon the parallelism of the visual axes of the eyes. Thus it can be seen that any deviation of the axes is not normal. However, some slight tendency of the eyes to deviate from the normal parallelism at near or distance can be included in the normal limits. A tendency of one of the eyes to deviate inward (*esophoria*) up to 2 prism diopters, a tendency for them to deviate out (*exophoria*) up to 2 prism diopters, a vertical deviation (*hyperphoria*, *hypophoria*) of  $\frac{1}{2}$  to  $\frac{3}{4}$  prism diopters, and finally a tendency for the vertical meridian of the cornea to rotate either temporally or nasally (*cyclophoria*) up to 5 degrees all can be designated as the normals of muscle balance. Parallelism of the visual axes is called *orthophoria*, while a tendency for deviation is called *heterophoria*. A manifest deviation of the eyes is called a *tropia* (turning in of a visual axis is *esotropia*; out, *exotropia*; torsional, *cyclotropia*; vertically, *hypertropia* or *hypotropia*).

The normal muscle balance largely depends on a ratio between adduction to abduction as 3 is to 1 at a distance of 33 cm. Adduction refers to the ability of the eyes to converge when prisms are placed before them separating or diverging the images, and abduction refers to the ability of the eyes to diverge when

prisms are used to converge the images. The average or normal abducting power is from 2 to 8 diopters, while the averaging adducting power is from 15 to 18 diopters, although it varies more than abduction.

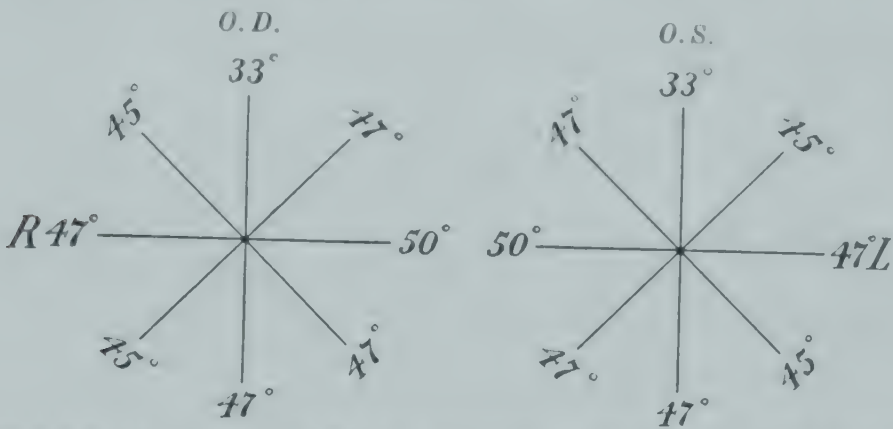


Fig. 176. Peter's method of recording fields of rotation. (Peter, L. C.; *The Extra-Ocular Muscles: A Clinical Study of Normal and Abnormal Ocular Motility*, Lea & Febiger.)

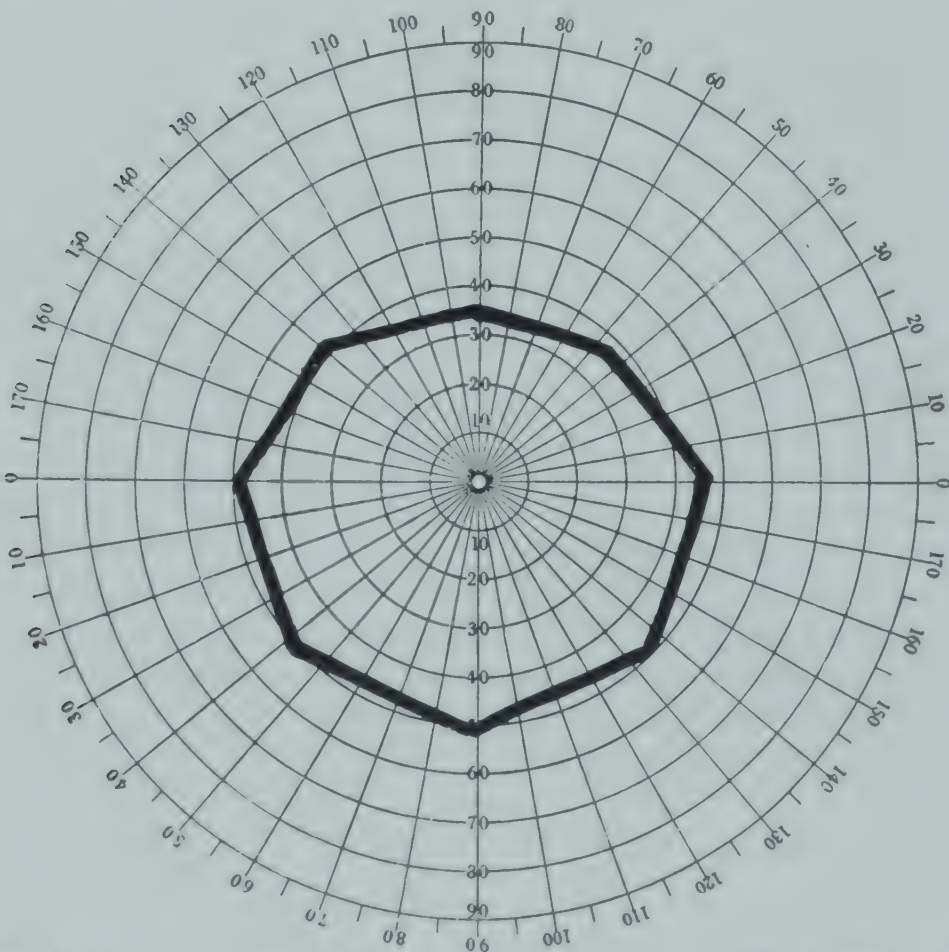


Fig. 177. Method of recording field of rotation on a perimetric chart. (Peter, L. C.; *The Extra-Ocular Muscles: A Clinical Study of Normal and Abnormal Ocular Motility*, Lea & Febiger.)

A ratio of hyperduction or supraduction to hypoduction or infraduction of  $1\frac{1}{2}$  to 1 is normal. The supraducting power normally is 2 to 3 diopters, while the average normal infraducting power is between 2 and 4 diopters.

Normal cycloduction or torsion permits movement 5 degrees temporally or nasally, the vertical meridian of the eyeball being the criterion for measurement.

FIELD OF FIXATION. The field of fixation is defined as the base of a cone, the apex of which is the center of rotation of the eyeball, as the eye is rotated to its extreme limits in all directions, foveal (central) vision at all times marking or defining the base of the cone.

TEARS

The secretion of the lacrimal glands is a clear, salty, slightly alkaline, watery fluid. There is a constant output of tears throughout all the waking hours, which for a sixteen-hour day has been estimated at from 0.5 to 0.66 gm.

TABLE 269  
COMPOSITION OF TEARS (GM. PER 100 ML.)  
(Duke-Elder, 1932)<sup>7</sup>

	<i>Ridley-Brown (1930)</i>
Total solids.....	1.8
Total nitrogen.....	0.158
Nonprotein nitrogen.....	0.051
Urea.....	0.03
Protein.....	0.669
Albumin.....	0.394
Globulin.....	0.275
Sugar.....	0.65
NaCl as chlorides.....	0.658
Na as Na <sub>2</sub> O.....	0.60
K as K <sub>2</sub> O.....	0.14
Ammonia.....	0.005

SCHIRMER METHOD OF TESTING HYPERSECRETION OR HYPOSECRETION OF LACRIMAL FLUID. Place the end of a strip of Whatman No. 41 filter paper, 35 by 5 mm., between the lower punctum and the eyeball.\* Normally, in young adults the entire length of the filter paper becomes moistened in five or six minutes.<sup>2</sup> As age progresses, the amount of lacrimation becomes less. At the age of forty years one-third of normal persons show a relative deficiency, moistening less than 15 mm. after five minutes. Moistening 5 mm. or less is quite likely to be the cause of symptoms.<sup>9</sup>

THE PHYSIOLOGIC BLINDSPOT (OF MARIOTTE)

The blind spot represents the projection onto the field of the optic nerve and is a negative, rather than a positive, scotoma. Normal small variations occur in its size and position. It is 5.5 degrees wide and 7.5 degrees high; the center of it is 15.5 degrees temporal to fixation and approximately 1.5 degrees below the horizontal meridian. The distance of the blind spot from fixation increases as hyperopia increases and diminishes as myopia increases. These

\* Fold the upper 5 mm. and place this part between the lower lid and the eyeball. This portion is not considered in the measurements.

Dimensions of the blindspot refer to absolute blindness, in addition to which there is a narrow band of relative blindness of 1 degree width surrounding the absolute blindspot.<sup>2, 13</sup>

## VISUAL FIELDS

**PERIPHERAL FIELD.** The extent of the normal field depends on the integrity of the retina, optic nerve chiasm, optic tract, external geniculate body, geniculocalcarine pathway, and occipital cortex.

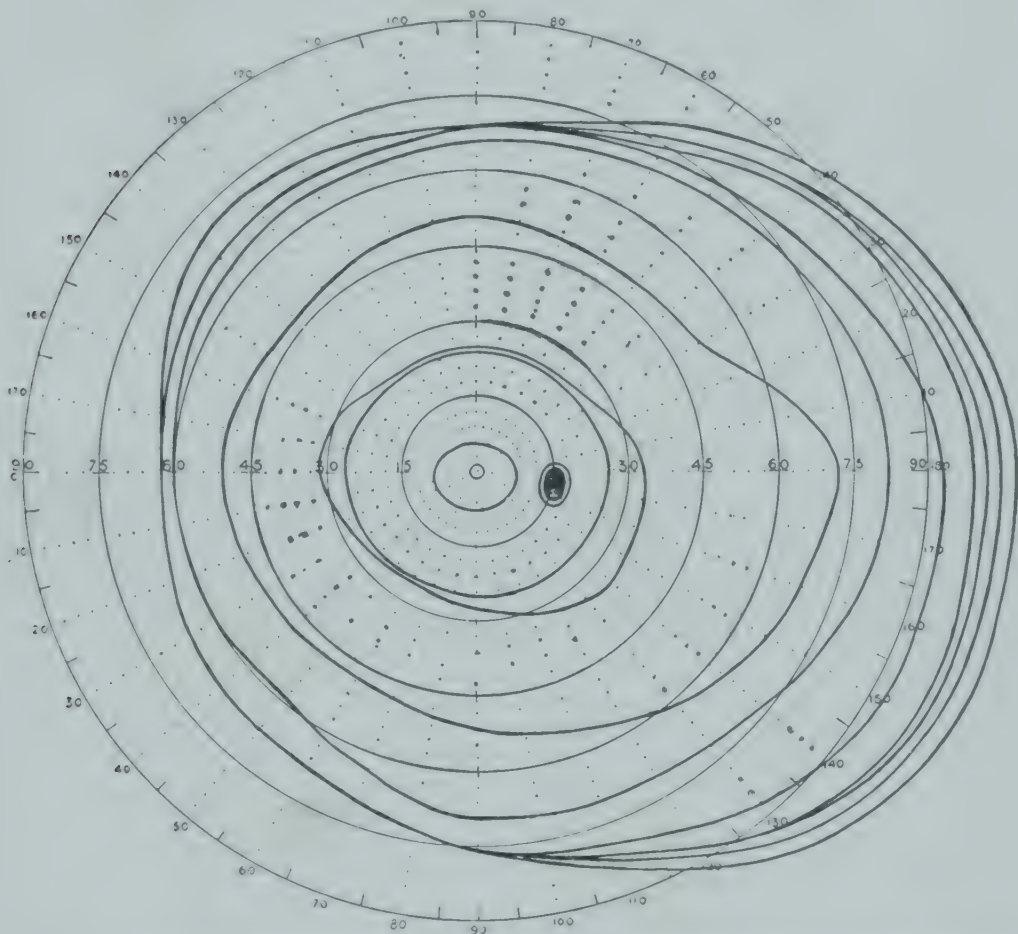


Fig. 178. Chart of the visual field of the right eye, showing the isopters from the periphery inwards to the center for 160/1000, 80/1000, 40/1000, 20/1000, 10/1000, 5/1000, 5/2000, 3/2000, 1/2000, 1/4000 and 0.63/4000. The numerator of each fraction represents the diameter of the test object in millimeters, the denominator the distance from the patient. As the test object is reduced in size, the field becomes smaller, slowly at the periphery, but rapidly towards the center. On the nasal side the larger test objects all give the same extent of field, so that the nasal edge of the field is perpendicular, the temporal edge being steeply sloping. The geometrical center of the field is about 20 degrees to the outer side of the visual axis or physiological center. (Traquair, H. M.: Clinical Perimetry, London, Henry Kimpton.)

Normally, a vertical line drawn through the point of fixation divides the field into a smaller nasal and a larger temporal half.

When a 3 mm. white test object is used on the perimeter (330 mm.) with 7.5 foot-candles of illumination, the normal field of vision extends 60 degrees nasally, 60 degrees superiorly, 75 degrees inferiorly and approximately 90 to 95 degrees temporally. With a fixed distance from the perimeter, the size of the

field may vary with size, color, speed of movement of the test object and with the preexposure.<sup>2</sup>

TABLE 270  
CLINICAL PERIMETRY  
(Traquair, 1942)<sup>13</sup>

Visual Angle	Object mm.	Distance mm.	Blue (Degrees)				Red (Degrees)				Green (Degrees)			
			Out	Down	In	Up	Out	Down	In	Up	Out	Down	In	Up
1.7'	1	2000	4.4	3.5	4.4	3.2	2	1.8	0.2	1.3	1.6	1.4	1.3	1.3
3.4'	2	2000	7.3	6.4	7.7	5.3	4	2.4	3.7	3.0	3.8	2.5	3.2	2.5
5.1'	3	2000	11	11	13	8	6	4.5	6.5	4.2	5	3.0	4.6	3.0
8.6'	5	2000	17	14	18	12	8	5	8	6	7	4.6	7	5.0
17.2'	10	2000	27	22	25	20	13	9	13	8	9	7.6	9.7	6.6
34.4'	20	2000	33	28	32	27	20	13	18	13	15	10	14	9.6
1° 9'	40	2000	...	...	...	...	32	20	20	19	22	16	17	14
10.4'	1	330	38	16	23	15	13	7	11	8	6	4	6	4
20.8'	2	330	50	20	26	17	22	11	14	11	13	7	10	6
31.2'	3	330	74	29	30	24	42	13	17	15	17	18	12	9
52.0'	5	330	80	33	35	30	53	21	23	22	28	12	14	12
1° 44'	10	330	87	47	43	37	79	35	29	31	49	16	21	18
3° 28'	20	330	89	55	46	41	85	46	36	37	65	21	22	21
6° 56'	40	330	92	58	48	43	87	52	41	42	70	30	29	29

CENTRAL FIELD. At a distance of 750 mm. a white spherical test object 1 mm. in size against a gray tangent screen is used, illuminated with 7.5 foot-candles of artificial daylight. The average normal field extends 26 degrees nasally, 26 degrees superiorly, 33 degrees temporally and 28 degrees inferiorly; the test object is moved at the rate of 100 mm. per second from nonseeing to seeing areas.

TABLE 271  
ISOPTERS IN THE NORMAL FIELD  
(Traquair, 1942)<sup>13</sup>

Visual Angle	Object Mm.	Distance (Mm.)	Out	Out Down	Down	In Down	In	In Up	Up	Out Up	Reciproca Value of Visual Angle
9°	160	1000	107	102	76	67	62	72	69	95	1
4.5°	80	1000	104	99	76	67	62	72	69	91	2
2.25°	40	1000	101	96	76	67	62	72	69	91	4
1.14°	20	1000	99	96	76	67	62	72	69	88	8
34.2'	10	1000	93	89	76	67	62	67	69	79	16
17.2'	5	1000	82	72	69	59	60	64	66	75	32
8.6'	5	2000	72	62	51	47	50	47	51	50	64
4.3'	2.5	2000	33	34	27	25	31	25	24	25	128
2.1'	2.5	4000	10	17	13	12	15	15	11	12	256
1.0'	1.25	4000	10	9	8	7	6	6	4	6	512
0.5'	0.63	4000	About 1° 20' Recognisable at the fixation point								1024
0.45'	0.63	4800									1236

It is evident from this table that the visual field has a steep edge.

TABLE 272

EXTENT OF THE FIELD FOR WHITE  
(Duke-Elder, 1932)<sup>7</sup>

Visual Angle	Object (Mm.)	Distance (Mm.)	White			
			Out	Down	In	Up
For the perimeter:						
52'.....	5	330	100	75	60	60
31.2'.....	3	330	95	75	60	60
10.4'.....	1	330	75	50	50	50
For the campimeter:						
8.6'.....	5	2000	72	50	50	50
5.1'.....	3	2000	37	30	30	25
1.7'.....	1	2000	26	26	26	26
1.0'.....	1.25	4000	10	8	6	4
0.5'.....	0.63	4000	Recognizable 1° round the fixation point			

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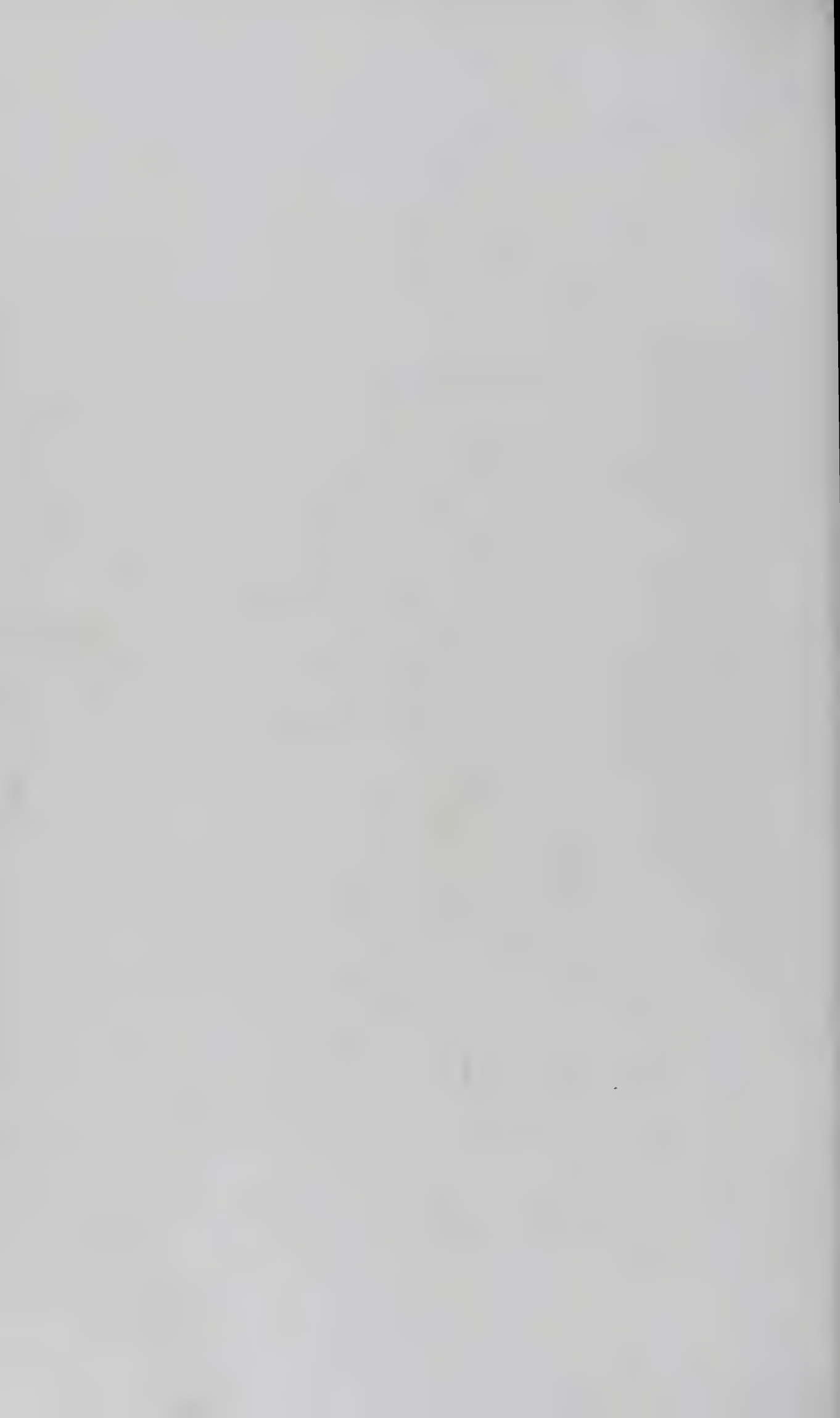
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Section XIII

THE EAR

(Normal Values in Otology)



## Chapter 55

### THE EAR

THE EAR IS divided anatomically into three parts: the external ear, the middle ear and the internal ear.

#### EXTERNAL EAR

The external ear includes the auricle and the auditory canal.

**AURICLE.** The size of the auricle in men is as follows: length, 50 to 80 mm.; width, 32 to 52 mm. In women the length is 50 to 75 mm., and the width is 28 to 45 mm. Politzer<sup>7</sup> gives the following limits: the superior limit is on a line with the eyebrow, and the inferior limit on a line with the tip of the nose. The



Fig. 179. The auricle. (Ballenger, W. L., and Ballenger, H. C.: Diseases of the Nose, Throat and Ear, Lea & Febiger.)

angle formed by the ear with the head varies up to 30 degrees. A larger angle causes a conspicuous protrusion of the ear. For the structures comprising the auricle, see Figure 179.

**AUDITORY CANAL.** The width of the canal varies from a goose quill to a size sufficient to insert a finger. It is narrowest at the isthmus, which is 7 to 8 mm. from the anterior margin of the drum to 1 to 2 mm. from the posterior margin. The transverse diameter at the isthmus is about 6 mm. The length of

the canal according to Troltsch (cited by Politzer<sup>7</sup>) is as follows: superior wall, 21 mm.; inferior wall, 26 mm.; anterior wall, 27 mm.; posterior wall, 22 mm.; and the entire length averages 24 mm., of which one-third is cartilaginous. For anatomical details, see Figure 180.

### MIDDLE EAR

The middle ear includes the membrana tympani, the ossicles and the eustachian tube.

**MEMBRANA TYMPANI (EAR DRUM).** This takes the shape of the osseous ring and the medial end of the external auditory canal. It may be oval, elliptical or heart-shaped. Its size according to Politzer<sup>7</sup> is 9.5 to 10 mm. from above down

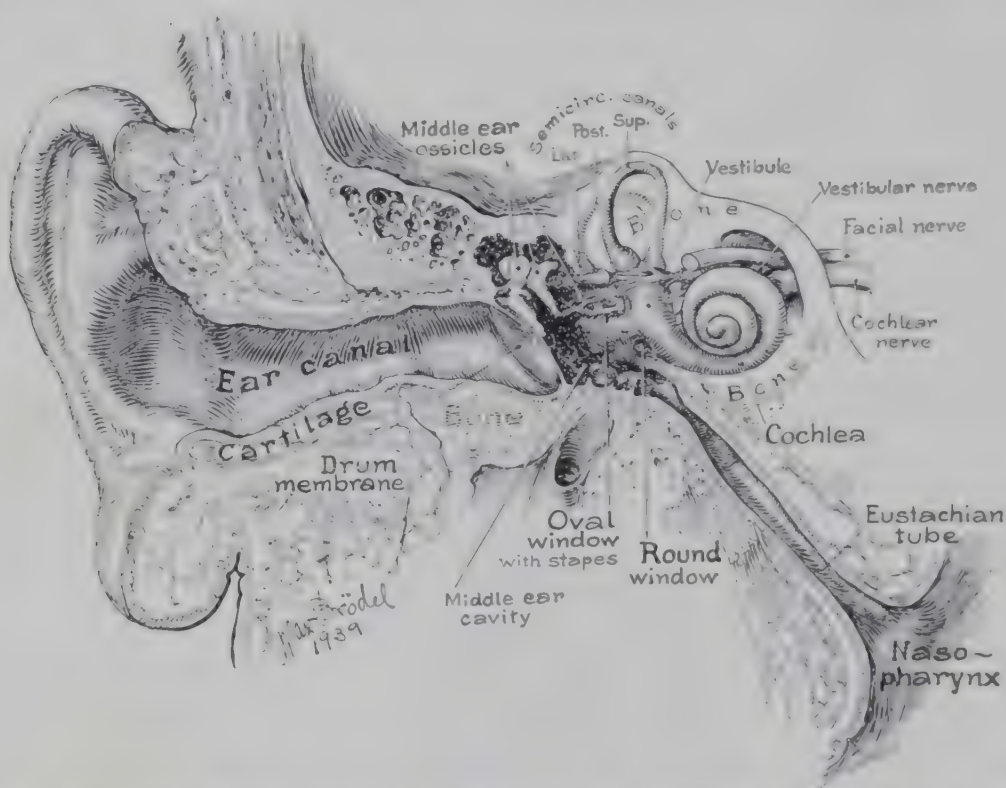


Fig. 180. The auditory canal; the middle and inner ear. (Unpublished drawing of The Anatomy of the Human Ear, by Max Brödel, assisted by Malone, Guild and Crowe.)

(greatest diameter) and 8.5 to 9 mm. transversely. According to Henle (cited by Politzer), its thickness is 0.1 mm.

Mackenzie<sup>5</sup> gives the following as requisite for a normal drum: (a) it should be intact, (b) brilliant, (c) translucent; (d) it should neither be retracted nor bulging; (e) the superior half should be larger than the inferior, and the posterior half larger than the anterior; and (f) it should be normally mobile with a Siegel otoscope and with Politzer inflation.

### INNER EAR (LABYRINTH)

The inner ear consists of an osseous labyrinth in which is a membranous labyrinth with its nerve endings (auditory nerve) and its ganglia.

**OSSEOUS LABYRINTH.** The osseous labyrinth is divided into three parts: the vestibule, semicircular canals and the cochlea. The entire organ is about

0 mm. in the bony axis and is located in the petrous portion of the temporal bone (Fig. 180).

**MEMBRANOUS LABYRINTH.** This is enclosed within the osseous labyrinth and has similar parts except that there are two parts instead of one vestibular cavity. These parts are the utricle and the saccule. The fluid in the osseous canals is perilymph. The membranous canals are filled with endolymph and surrounded by perilymph.

**LABYRINTHINE FLUID.** The fluid in the membranous labyrinth, called endolymph, is secreted by the striae vascularis in the cochlea. It is diffused into the perilymph and out through the saccus endolymphaticus into surrounding venous spaces by osmosis. The perilymph is in the bony labyrinth surrounding the membranous labyrinth and communicates with the cerebrospinal fluid through the aqueductus cochlearis. The *osmotic pressures* of these fluids are reported by Aldred and his co-workers<sup>1</sup> to be higher than those of blood and cerebrospinal fluid. Comparison of their average values, expressed as grams of sodium chloride per 100 grams of water, is as follows: blood, 0.994; cerebrospinal fluid, 1.017; perilymph, 1.046; and endolymph, 1.058.

## HEARING

The normal hearing range in man for measured sound is from 16 to 22,000 cycles, double vibration (d. v.) per second.

Intensity of hearing may be recorded in sensation units (S.A.), decibels (d.b.) or the percentage loss of hearing. A sensation unit is the smallest fractional change in intensity of a sound perceived by a person of normal hearing (subjective). A decibel, which is a unit of relative intensity, is the smallest increase in sound intensity applied which can be appreciated by the normal ear.\*

**HEARING TESTS. VOICE.** The patient places a moistened finger in the ear not to be tested, and a low conversational or whispered voice is used to test the other ear. In an ordinary office 20 feet is taken as the normal distance at which voice sounds are still audible. The record is made in fractions of 20, e. g., 10/20, 15/20 and so on. The average range of conversational voice is between 300 and 3000 cycles. The male voice may vary between 80 to 7800 frequencies, including overtones. The female voice ranges from about 160 to 10,256 cycles.

**AUDIOMETER.** This instrument records eight frequencies, each in a large range of intensities. It consists of a frequency oscillator, an attenuation potentiometer which regulates the volume of sound on a receiver. There is also a bone conduction receiver. The record is made in decibel loss. A curve indicating the limit of serviceable hearing for each pitch is usually provided on the record. A similar line for bone conduction is also marked. Percentage of hearing loss is obtained by adding the loss in 512, 1024 and 2048 cycles, and dividing by 3 and multiplying by 0.8.

**GRAHE'S TEST FOR UTRICULAR FUNCTION.**<sup>3</sup> This is done on a special table having one frame within another in a vertical position, permitting tilting of the patient from side to side, backward and forward. The patient is strapped

\* For details regarding decibels, the reader is referred to the article by R. J. Hunter.<sup>4</sup>

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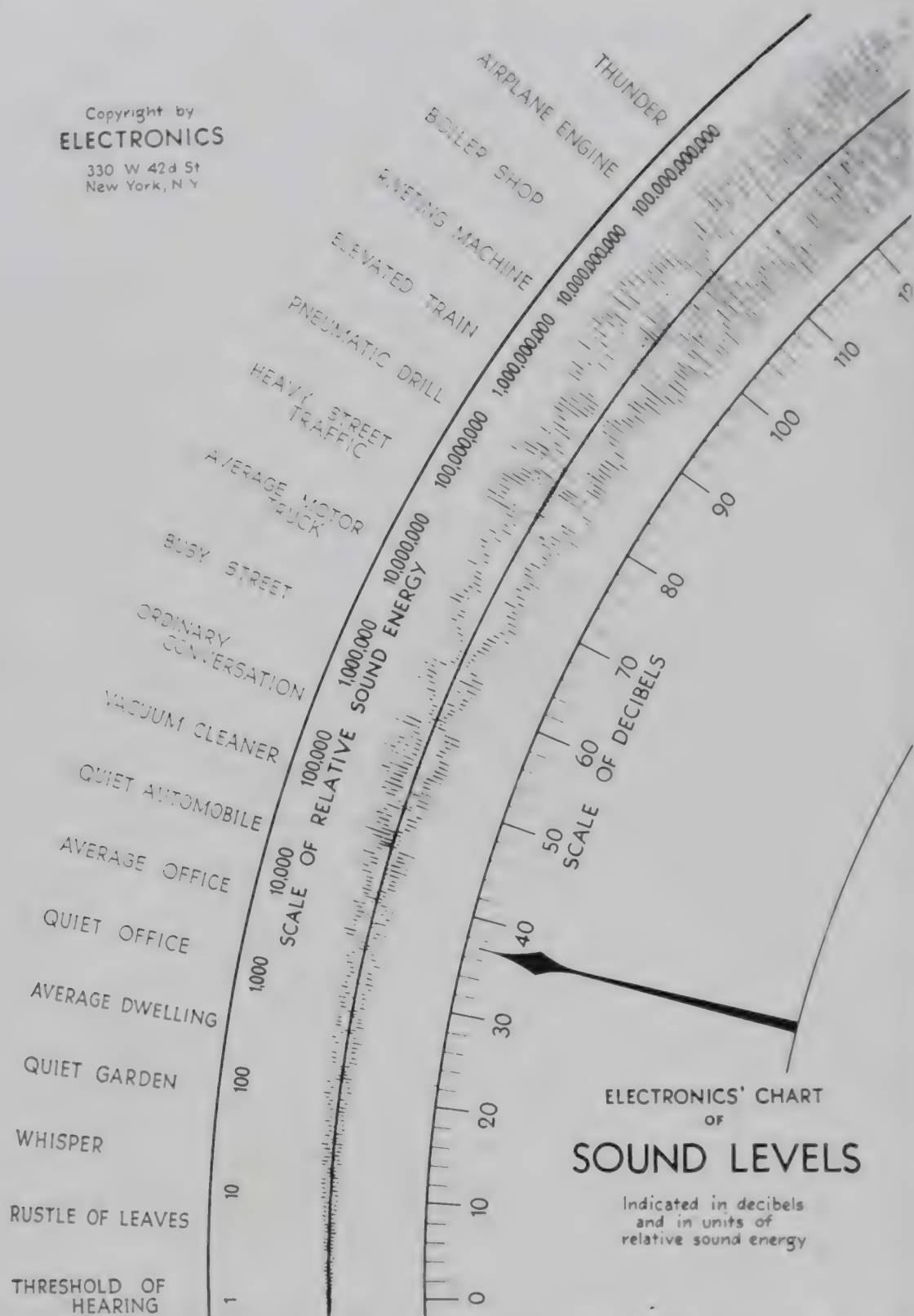


Fig. 181. Chart showing the noise level in situations which we constantly encounter. A quiet office has a background noise of about 30 decibels, an average office about 40 decibels. The noise level of ordinary conversation is between 50 and 60 decibels. (Courtesy of Electronics.)

to the inner frame. With the eyes closed, the table is tilted alternately in four directions—backward, forward, to the right and to the left—then brought to the vertical position. Normally, a patient when brought up from either side will believe that he is in a vertical plane at 5 to 10 degrees before he actually

TABLE 273

ARITHMETIC MEANS AND STANDARD DEVIATIONS FOR DISTRIBUTION OF THRESHOLD ACUITY MEASUREMENTS BY AIR CONDUCTION\*

(National Health Survey)<sup>6</sup>

Male

Age Range in Years	Number of Ears	Arithmetic Mean in Decibels								Standard Deviation of Distribution							
		Audiofrequency in Cycles								Audiofrequency in Cycles							
		64	128	256	512	1024	2048	4096	8192	64	128	256	512	1024	2048	4096	8192
under 10.....	316	4.1	4.9	8.2	7.8	2.4	0.8	8.5	10.2	6.2	6.4	5.9	6.1	6.7	7.0	11.1	12.4
to 19.....	1176	2.6	3.6	7.5	6.9	0.9	0.2	8.5	10.5	6.5	6.7	6.3	6.4	6.2	7.5	12.2	14.3
to 29.....	684	2.1	2.5	6.8	6.5	1.0	0.1	13.7	11.5	6.5	6.8	6.0	6.5	6.4	7.5	16.4	15.6
to 39.....	800	2.6	3.2	7.8	7.2	2.0	2.4	21.6	18.1	6.3	6.6	6.1	6.4	6.9	8.0	18.8	13.2
to 49.....	640	3.5	4.1	8.8	7.8	3.1	4.4	28.3	25.0	6.6	6.9	6.3	6.4	6.4	8.6	20.1	19.4
to 59.....	282	3.8	4.4	9.3	8.5	3.9	6.3	35.0	34.6	6.5	7.1	6.1	6.9	7.4	8.4	18.4	19.6
and over.....	106	4.0	4.6	9.8	8.9	3.6	8.3	39.7	41.7	6.4	7.3	6.4	7.0	7.6	8.1	17.0	19.9
Female																	
under 10.....	280	5.0	6.0	9.3	8.9	2.3	0.7	6.1	9.2	6.2	6.1	6.6	6.4	6.2	6.8	7.8	10.0
to 19.....	1278	2.9	4.0	7.8	7.0	0.4	-1.7	5.4	5.9	6.6	6.6	6.5	6.7	6.3	6.9	8.8	10.9
to 29.....	1130	3.0	3.7	8.2	7.2	1.2	-0.3	7.8	8.5	6.7	6.8	6.5	7.0	6.7	7.2	9.9	10.8
to 39.....	1278	4.0	5.0	9.0	8.4	2.5	1.7	10.5	11.3	6.6	6.7	6.4	6.8	6.5	7.2	9.8	11.6
to 49.....	876	5.0	6.0	10.0	9.6	3.6	3.4	14.0	16.2	6.6	6.8	6.4	6.7	6.6	7.1	10.8	14.3
to 59.....	364	5.9	7.1	11.3	10.8	5.1	5.0	17.3	23.7	6.2	6.6	6.3	6.5	7.5	7.9	12.6	15.2
and over.....	114	7.3	8.7	12.4	12.6	6.4	7.9	22.2	34.8	7.0	7.4	6.6	7.4	7.5	7.4	12.9	16.9

\* Both ears of 2002 males and 2660 females with a clinical history of normal hearing for speech in both ears, classified according to audiofrequency and 10-year age groups.

TABLE 274

ARITHMETIC MEANS AND STANDARD DEVIATIONS FOR DISTRIBUTION OF THRESHOLD ACUITY MEASUREMENTS BY BONE CONDUCTION\*

(National Health Survey)<sup>6</sup>

Male

Age Range in Years	Number of Persons	Arithmetic Mean in Decibels							Standard Deviation of Distribution						
		Audiofrequency in Cycles							Audiofrequency in Cycles						
		256	512	1024	2048	4096	8192	256	512	1024	2048	4096	8192	256	8192
under 10.....	158	52.2	50.3	53.9	48.6	53.6	27.8	7.7	7.4	8.3	8.0	9.0	10.0	7.7	10.0
to 19.....	588	53.7	52.6	55.7	48.3	53.2	29.0	7.5	7.1	8.0	8.3	10.7	11.5	7.5	11.5
to 29.....	342	55.7	55.4	57.4	49.4	57.3	31.4	7.3	7.7	7.1	8.6	11.8	11.8	7.3	11.8
to 39.....	400	56.0	56.5	57.3	51.8	63.0	36.6	8.1	8.0	8.1	8.8	12.6	13.0	8.1	13.0
to 49.....	320	56.0	57.5	58.4	53.8	67.7	41.9	8.4	7.9	8.1	9.1	13.2	13.8	8.4	13.8
to 59.....	141	56.1	58.5	58.6	56.9	72.9	48.5	8.9	9.0	8.3	8.3	12.8	13.4	8.9	13.4
and over.....	53	56.2	57.9	58.9	57.6	73.5	52.0	9.1	9.9	9.0	8.3	12.9	13.4	9.1	13.4
Female															
under 10.....	140	52.9	52.6	54.4	48.0	51.3	27.7	8.4	7.5	7.7	7.8	9.3	10.0	8.4	10.0
to 19.....	639	53.5	53.1	55.2	48.2	52.4	26.9	7.9	7.8	7.9	8.5	9.1	9.5	7.9	9.5
to 29.....	565	54.4	56.2	57.2	50.2	55.1	30.5	8.0	8.3	8.1	8.8	9.0	9.0	8.0	9.0
to 39.....	639	55.6	57.4	58.5	52.0	57.0	33.8	7.9	8.1	7.9	8.4	8.9	9.5	7.9	9.5
to 49.....	438	55.7	58.7	59.6	54.1	60.4	38.3	7.8	8.0	7.1	9.0	9.7	11.4	7.8	11.4
to 59.....	122	56.9	60.2	61.9	56.6	62.8	43.4	7.2	7.2	8.3	9.0	9.9	11.5	7.2	11.5
and over.....	57	56.0	61.0	62.7	58.5	66.1	51.3	8.9	7.3	6.4	7.3	11.3	12.0	8.9	12.0

\* On 2002 males and 2660 females with a clinical history of normal hearing for speech in both ears, classified according to audiofrequency and 10-year age groups.

reaches the vertical. From an inclination backward of 30 degrees the patient will feel that he is in a vertical position, at 5 to 15 degrees, in the backward position. From an inclination of 20 degrees forward he will feel that he is in a vertical position when he is actually in a slightly backward position.

TABLE 275

## NORMAL REACTIONS TO THE ROTATION TEST

<i>Test</i>	<i>Reaction</i>
1. Spontaneous.	1. No nystagmus, vertigo, past pointing or falling.
2. Turn <i>to right</i> 10 times in 20 seconds with head 30 degrees forward.	2. Horizontal nystagmus <i>to left</i> , 24 seconds duration.
3. Turn <i>to right</i> 10 times in 10 seconds and ask patient to say in which direction he is turning; for example, right or left.	3. Will feel himself going in direction turned while turning. When chair is suddenly stopped, he will <i>think</i> he is going in opposite direction for 25 seconds. This indicates normal quantitative vertigo.
4. Turn <i>to right</i> 10 times in 10 seconds with head 30 degrees forward.	4. Test pointing, past points: (12 inches to right with both hands, then twice more for a shorter distance).
5. Turn <i>to left</i> 10 times in 20 seconds with head 30 degrees forward.	5. Horizontal nystagmus <i>to right</i> , 24 seconds duration.
6. Turn <i>to left</i> 10 times in 10 seconds and repeat as in 3.	6. Same as in 3, except that vertigo is in opposite direction.
7. Turn <i>to left</i> 10 times in 10 seconds with head 30 degrees forward.	7. Test pointing, past points: (12 inches to right with both hands, then twice more for a shorter distance.)

In the test the eyes should be closed and the horizontal canals only are tested; both sides are tested at the same time. The vertical canals are not usually tested by this method, although that can be done by repeating the tests with the head in such position as to bring the canals into nearly horizontal plane; e.g., 90 degrees forward or 60 degrees backward. Reactions will be accordingly.

TABLE 276

## NORMAL REACTIONS TO THE CALORIC TEST (MASS IRRIGATION)

<i>Test</i>	<i>Reaction</i>
1. Douche right ear with water 68°F., head forward. Note length of time required to produce reaction.	1. Requires 40 seconds' douching. Rotary nystagmus <i>to left</i> . Past pointing 8 inches to right with each hand. Vertigo to left and tendency to fall to the right.
2. After above has been quickly noted, bend head back 60° and again note reactions.	2. Same as above except that nystagmus is <i>horizontal</i> .
3. Repeat 1 and 2 in left ear.	3. The reactions are the same, but in the opposite direction.

VESTIBULAR APPARATUS TESTS (BÁRÁNY TESTS). The vestibular apparatus consists of the semicircular canals and the vestibule (utricle and saccule). The semicircular canals perceive changes in position in rotary movement (kinetic). The utricle and saccule perceive changes in position in a straight line, back and forth, or up and down.

Tests applied to the semicircular canals have attained more practical results than those applied to the utricle and saccule. The tests applied to the semicircular canals are the "rotation," "caloric" and "galvanic."

The normal reactions to rotation and caloric tests are nystagmus, vertigo, past pointing and falling (see Table 277).

**GALVANIC TEST.** A galvanic plate is used (direct current), or special batteries, having a positive pole (anode) and a negative pole (cathode). The bipolar method may be used when one pole is applied to each ear and so only one or

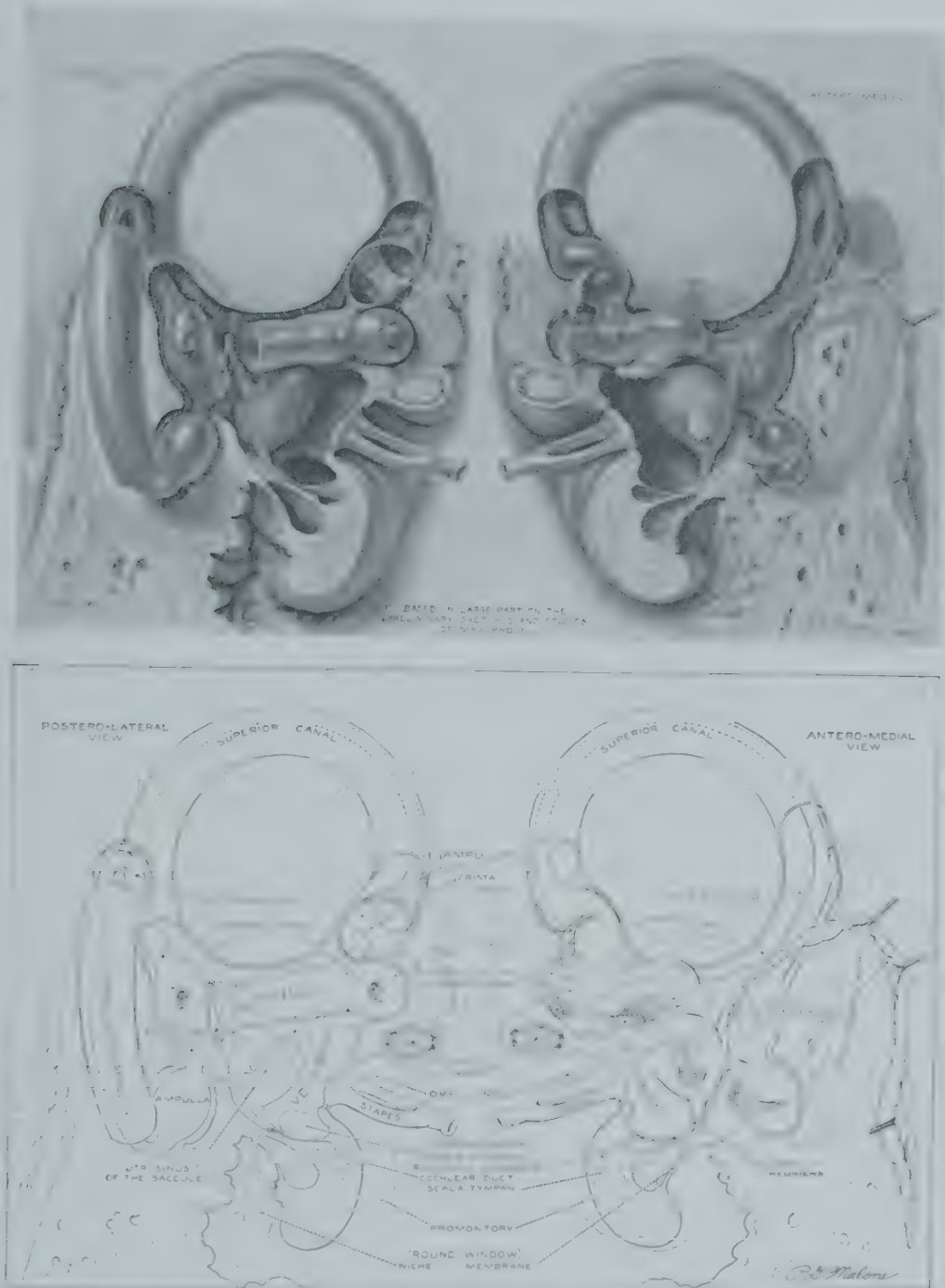


Fig. 182. Vestibular apparatus. (Unpublished drawings of The Anatomy of the Human Ear, by Max Brödel, assisted by Malone, Guild and Crowe.)

two milliamperes' current is required. The nystagmus is in the direction of the electric current flow, which is from the positive to the negative pole. When the positive pole is applied to the right ear, there is a rotary nystagmus to the left, vertigo to the left, falling and past pointing to the right (same as cold caloric). Changing the position of the head backward or forward makes no difference.

TABLE 277


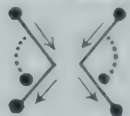
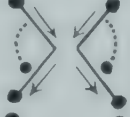
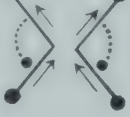
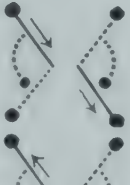


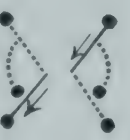
## NORMAL VESTIBULAR REACTIONS IN VARIOUS PLANES OF THE HEAD

(Shuster)

1. The diagrams represent the semicircular canals, and the clubbed ends the ampulae.
2. The canals are seen looking from above and facing the patient. The patient's right would therefore, be on the observer's left.
3. In a given test, the canals affected are recorded in the diagram, in a bold line; the others in a broken line.
4. The arrows represent the direction of the endolymph flow, after the test is applied; and the type of nystagmus, in the column of nystagmus.
5. The combined canals represent the vertical ones; the upper, the posterior; the lower, the anterior; the single, the horizontal. The ampulae are in the normal position in the head.
6. The direction of nystagmus (quick—component) is as it is seen on the patient.
7. The direction of the arrows is with reference to the patient.

Test	Posterior		Nystagmus	Vertigo	Past Pointing	Falling
	Right	Left				
	Anterior					
Turn to right, head 30° forward			Horizontal to left →	To left in horizontal plane	To right	
Turn to left, head 30° forward			Horizontal to right ←	To right in horizontal plane	To left	
Turn to right, head 60° back			Rotary right ↺	To left in horizontal plane, and sensation of falling to right when head is brought up	To right	To left, getting up
Turn to left, head 60° back			Rotary left ↻	To right in horizontal plane, and sensation of falling to left when head is brought up	To left	To right, getting up
Turn to right, head 90° forward			Rotary left ↻			
Turn to left, head 90° forward			Rotary right ↺			
Turn to right, head 120° forward			Rotary left ↻	To left in horizontal plane, and sensation of falling to left when head is brought up	To right	To right, getting up
Turn to left, head 120° forward			Rotary right ↺	To right in horizontal plane, and sensation of falling to right when head is brought up	To left	To left, getting up
Turn to right, head to right shoulder			Vertical down ↓		Up when head is brought up	Backward, getting up

TABLE 277—Continued

Test		Nystagmus	Vertigo	Past Pointing	Falling
Turn to left, head to right shoulder		Vertical up ↑			
Turn to right, head to left shoulder		Vertical up ↑		Down when head is brought up	Forward, getting up
Turn to left, head to left shoulder		Vertical down ↓		Up when head is brought up	Backward, getting up
Turn to right after head is turned 45° to right and inclined to right shoulder 90°		Oblique down to left when head is brought up ↘			
Turn to left in the above		Oblique up to right ↗			
Turn to right after head is turned 45° to left and inclined to right shoulder 90°		Oblique down to right when head is brought up ↘			
Turn to left in the above		Oblique up to left ↖			

## Caloric

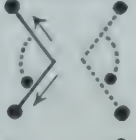
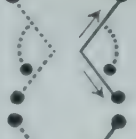
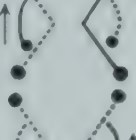
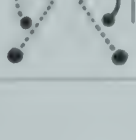


Hot water 68° F.) Occlude right ear, head 30° forward		Rotary left ↻	Sense of falling to left	To right	To right
Hot water 68° F.) Occlude left ear, head 30° forward		Rotary right ↻	Sense of falling to right	To left	To left
Hot water 68° F.) Occlude right ear, head 60° back		Horizontal to left →	Sense of falling to left	To right	To right
Hot water 68° F.) Occlude left ear, head 60° back		Horizontal to right ←	Sense of falling to right	To left	To left

TABLE 277—Continued

Test	<div>Posterior Right Left Anterior</div>	Nystagmus	Vertigo	Past Pointing	Falling
Douche right ear, head 120° forward		Horizontal to right ←	Sense of falling to right	To left	To left
Douche left ear, head 120° forward		Horizontal to left →	Sense of falling to left	To right	To right
(Hot water 112° F.) Douche in above positions		Opposite to cold	Opposite to cold	Opposite to cold	Opposite to cold

The above reactions are in accordance with the following physiological laws:

1. The eyes are always drawn in (slow component) in direction of endolymph movement (nystagmus opposite).
2. Vertigo is always in a direction opposite to the endolymph movement.
3. Past pointing is always in a direction opposite to the vertigo.
4. Falling is always in a direction opposite to the vertigo.

The unipolar method for conducting the galvanic test is regarded as more satisfactory than the bipolar. The positive pole is applied to the tragus of the side to be tested and the other pole at a distant part, e. g., neck. With this method more current, 4 milliamperes, is required. If less current is required the labyrinth is said to be hyperactive; if more is required, it is said to be hypoactive. The reaction may take place, even when the labyrinth nonfunctioning is of recent origin, through the eighth nerve, if that has not degenerated. After the inner ear has been degenerate for some time (two or three months) no galvanic reaction will appear.

CALORIC (KOBRAK) METHOD OF STIMULATION. This method is subject to many modifications; however, usually 5 ml. of water at 55° F. are injected against the posterior part of the drum, and observations are made of the time of appearance and duration of nystagmus. Normally, nystagmus appears after a latent period of twelve to twenty-five seconds and lasts about 100 seconds.

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Section XIV

THE NOSE

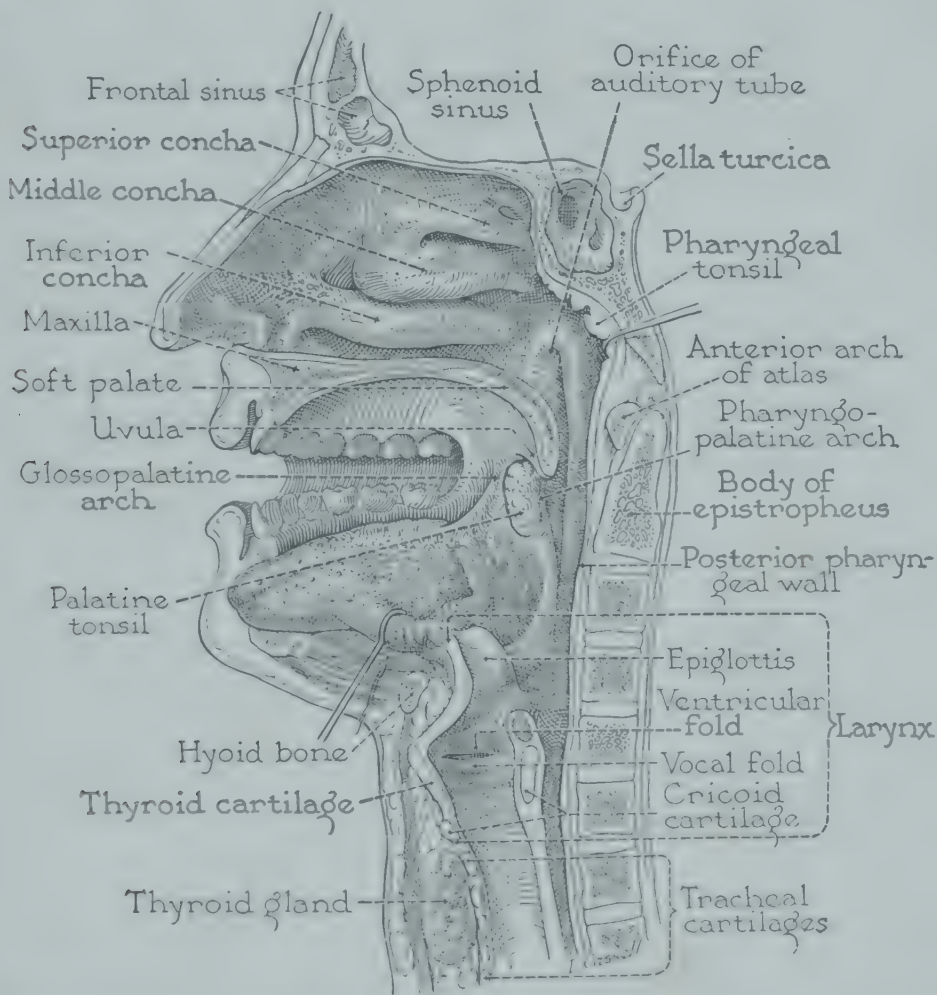
(Normal Values in Rhinology)



## Chapter 56

### THE NOSE

THE NOSE IS pyramid-shaped and projects anteriorly between the orbits. The root is that region attached to the frontal bone. The tip is the free point below. The dorsum is the line, straight or curved, between the root and the tip. The alae are the area containing the nostril. The columella is the septum separating the nostrils.



183. Sagittal section through the mouth, larynx, pharynx and nasal cavity. (Millard and King: Human Anatomy and Physiology.)

**SHAPE AND LENGTH.** From an esthetic point of view, the length of the nose is somewhat less than the length between the nostrils and the chin. The angle of the nose formed by the dorsal line of the nose to a line between the glabella and chin is, ideally, 30 degrees. The angle of the nose with the upper lip (nasolabial angle) is about 90 degrees (Fig. 184).

In early infancy the nose is usually concave with the tip turned up. It

becomes straight or convex in the adult. In old age it has a tendency to become convex with the tip turned down.

**NOSTRILS.** In infants the nostrils are horizontally inclined; in adults they assume a vertical position. The nostrils also vary in different noses. In the white race they are elliptical from above downward. In the Negro they are transverse and nearly round.

### OLFACTION

The olfactory area in the nose is in the superior part of the nasal cavity on the lateral wall, as well as the septal wall. Odor reaches the area by diffusion. Sniffing helps draw the air across the area.



Fig. 184. Straight nose of normal length, with nasal profile angle of 30 degrees and nasolabial angle of 90 degrees; considered ideal. (Fomon, S.: *The Surgery of Injury and Plastic Repair*, Williams & Wilkins Company.)

The sense of smell is a chemical stimulation of the nerve endings. The acuity of smell may vary slightly in a normally constructed nose. During menstruation a hyperacuity has been noted. Individuals may cultivate a special acuity for some substances; e. g., tea, coffee and wine tasters and perfumers have a keenly developed sense for these substances.<sup>7</sup>

**MEASUREMENTS OF SENSE OF SMELL.** Various methods have been described to test the sense of smell since Zwaardemaker's early studies in 1895. None of them, however, yields highly accurate information.

**PROETZ TEST.** Proetz<sup>7</sup> described an olfactometer which uses a series of different substances, each in dilution of ten different strengths. The diluent is liquid petrolatum. The minimum perceptible odor of each substance has been determined and expressed as the smallest amount of the substance in gram

a liter of petrolatum (light) with a specific gravity of 0.880. The first bottle contains the minimum amount perceived by a large number of normal persons. Its value is termed an "olfact." The second bottle (in intensity) contains twice the minimal amount, or 2 olfacts, and so on until the tenth, which is 10 olfacts (see Table 278).

TABLE 278

CONCENTRATIONS OF VARIOUS SOLUTIONS USED IN THE OLFACTOMETER, IN GRAMS PER LITER OF LIQUID PETROLATUM

(Proetz, 1941)<sup>7</sup>

<i>Iodo-</i> <i>form</i>	<i>Methyl</i> <i>Salic.</i>	<i>Amyl</i> <i>Alc.</i>	<i>Xylol</i>	<i>Nitro-</i> <i>Benzol</i>	<i>Phenol</i>	<i>Guaiacol</i>	<i>Cinnamon</i>	<i>Eugenol</i>	<i>Cou-</i> <i>marin</i>
0.0006	0.00074	0.00069	0.00432	0.00762	0.00480	0.00075	0.00026	0.00013	0.00019
0.0012	0.00148	0.00139	0.00865	0.01525	0.00960	0.00151	0.00053	0.00026	0.00038
*0.0025	*0.00297	*0.00275	*0.01730	*0.03050	*0.01921	*0.00302	*0.00106	*0.00053	*0.00077
0.0050	0.00594	0.00550	0.03560	0.06100	0.03842	0.00604	0.00212	0.00106	0.00154
0.0075	0.00891	0.00825	0.05190	0.09150	0.05763	0.00906	0.00318	0.00159	0.00231
0.0125	0.01485	0.01375	0.08650	0.15250	0.09605	0.01510	0.00530	0.00265	0.00385
0.0250	0.02970	0.02750	0.07300	0.30500	0.19210	0.03020	0.01060	0.00530	0.00770
0.0625	0.07425	0.06875	0.43250	0.76250	0.48025	0.07550	0.02650	0.01325	0.01925
0.1250	0.14850	0.13750	0.86500	1.52500	0.96050	0.15100	0.05300	0.02650	0.03850
0.2500	0.29700	0.27500	1.73000	3.05000	1.92100	0.30200	0.10600	0.05300	0.07700

\* Minimum amount perceived by normal persons.

TABLE 279

ODOROUS SUBSTANCES AND THEIR OLFACTORY COEFFICIENTS (M.I.O.)\*

(Elsberg and Levy, 1935)<sup>3</sup>

<i>Substance</i>	<i>Average Olfactory</i> <i>Coefficient</i>
	Cc.
Benzine.....	5.26
Oil of orange peel.....	8.34
Xylol.....	10.0
Oil of turpentine.....	10.7
Butyric acid.....	11.43
Asafetida (10 per cent).....	11.88
Oil of lemon.....	12.75
Oil of bitter almonds.....	13.08
Oil of rose.....	13.12
Oil of peppermint (20 per cent).....	13.77
Oil of cade.....	13.88
Oil of lavender.....	14.3
Vanilla.....	14.4
Creosote.....	14.5
Oil of heliotrope.....	14.68
Camphor.....	15.0
Oil of sassafras.....	15.42
Ground coffee.....	15.86
Oil of anise.....	15.94
Oil of cloves.....	17.22
Oil of cedarwood.....	32.65

\* "Minimal identifiable odor," or olfactory coefficient.

The nose should be free from obstruction. If there is edema of the membrane, it is shrunk with 2 per cent ephedrine on a cotton applicator, applied to the inferior and middle turbinates. The test is undertaken in a room without artificial odor, and the subject should not have smoked for several hours.

The bottle with the weakest concentration is first tried, then that with increased concentration, until the strength is reached in which the subject identifies the test substance.

ELSBERG TEST. Elsberg<sup>2</sup> devised a series of smell tests for the detection of brain tumors. Single blasts of air-plus-odor into the nose may be used and the minimal identifiable odor (M.I.O.) expressed in cubic centimeters may be obtained, or a constant stream of air-plus-odor may be injected into the nose at the rate of 2000 ml. per minute for thirty seconds. The constant stream causes olfactory fatigue. This may be followed by blast injections to determine the time required for the return to normal. Table 279 shows the minimal identifiable odor or olfactory coefficients for various substances.

According to Goetzl and Stone,<sup>5</sup> there is a diurnal variation in olfactory acuity.

THE SINUSES

There are eight nasal sinuses, four on each side of the nose: frontal, maxillary, ethmoid and sphenoid. They are lined with mucous membrane, contain air and communicate with the nasal cavity through a nasal opening, the ostium.

The *frontal sinus* is situated between the anterior and posterior plates of the frontal bone. It appears at about the age of three years, and gradually increases in size until about puberty.

The *maxillary sinus* is a pyramidal-shaped space in the superior maxillary bone. Its capacity is about 10 to 20 ml.

TABLE 280  
DEVELOPMENT OF THE SINUSES FROM BIRTH  
(Ballenger and Ballenger, 1943)<sup>1</sup>

	At Birth	1 Yr.	1-3 Yrs.	7 Yrs.	7-9 Yrs.	15-18 Yrs.
Maxillary . . . . .	Size of small bean	Gradual development to . . . . .				Fully developed
Ethmoid . . . . .	Present	Gradual development to . . . . .				Fully developed
Frontal . . . . .	Absent	Absent	Appearance	Pea-size	Distinct cavity	Fully developed
Sphenoid . . . . .	Present as a rule	Distinct cavity	Size of large pea	...	Fully developed	Fully developed

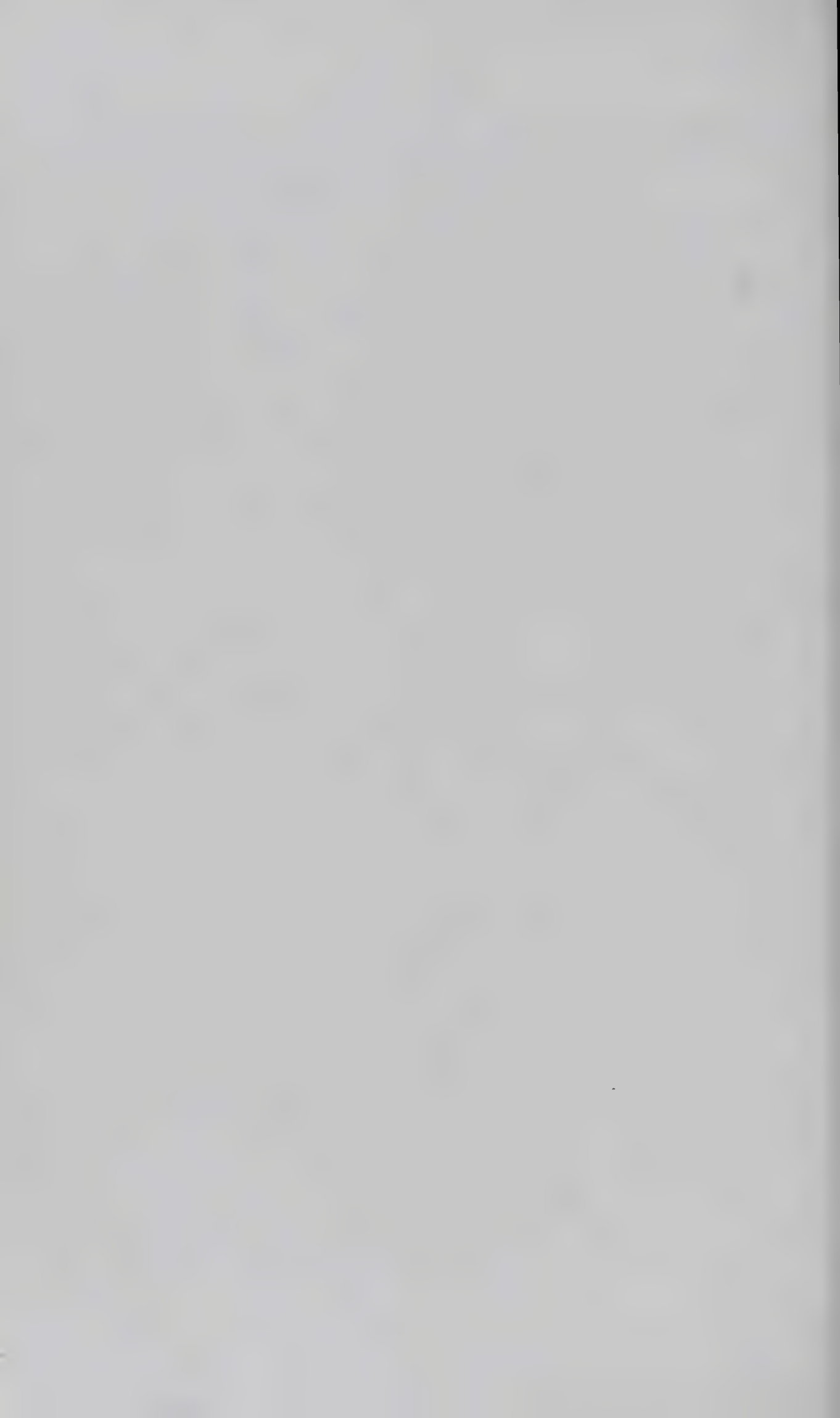
The *sphenoid sinus* is a space in the body of the sphenoid bone on each side. The cavities on each side are not symmetrical; often one is large and the other small. A partition divides the two, not necessarily in the midline. The sinus begins to develop between the first and second year and is fully formed at about the age of eight years, and frequently has extensions into the surrounding cranial bone. Thus it may surround the optic foramen and extend into the greater and lesser wings of the sphenoid bone.

The *ethmoid sinus* is a group of 2 to 10 or 15 air cells, lined with epithelium.

um, each one having an opening for drainage of mucus. The capacity of the group in each side averages about 9 to 10 ml. This sinus is present at birth and gradually develops in size until the age of fifteen to eighteen years.

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Section XV

ENDOCRINES

(Normal Values in Endocrinology)



## Chapter 57

### ANDROGENS AND 17-KETOSTEROIDS

SOURCES. Androgens or "male sex hormone" are produced in the human being from two chief sources, the testes and the adrenal cortex; there is some evidence that the ovaries may secrete small amounts of androgens, but this point has not been settled.

In the testes, androgens are secreted by the interstitial cells of Leydig under the stimulation of one of the pituitary gonadotrophins, namely, the "interstitial-cell-stimulating" or "interstitial-cell-stimulating" fraction. The androgen secreted by the testis is *testosterone*. This endocrine function of the testes is thus distinct from its spermatogenic function, which is supposedly under the influence of the follicle-stimulating hormone or gametokinetic fraction. Whether another testicular hormone is produced also by the spermatogenic tissue is not known.

A number of androgenic hormones are normally secreted by the adrenal cortex, probably under the influence of the adrenocorticotrophic hormone of the anterior pituitary. It appears that in both men and women the larger part, probably about two-thirds of the androgenic material, is of adrenal origin. This is based upon the facts that women excrete almost as much androgen as men, that urinary androgen excretion is increased in adrenal cortical hyperfunction and in patients with adrenal cortical tumors, and that androgens have been isolated from adrenal extracts.

The term "17-ketosteroids" refers to those steroids having a ketone group on the seventeenth carbon atom. It is often used in clinical terminology to designate the "urinary androgens," because the androgenic substances found in the urine are 17-ketosteroids. The terms are not strict synonyms, however, since there are some androgens which are not 17-ketosteroids, and, conversely, there are other 17-ketosteroids which are not androgenic. Seventeen-ketosteroids are derived from the testes, the adrenal cortex and the ovary. Estrone is the chief ovarian 17-ketosteroid, but since it is a phenolic substance it can be separated from those of testicular and adrenal origin, which are primarily in the neutral fraction. Thus, the terms "neutral" or "nonphenolic" 17-ketosteroids more nearly represent the urinary androgens.

### BIOCHEMISTRY OF THE ANDROGENS AND 17-KETOSTEROIDS

Testosterone, the androgen made by the testes, is the most potent of the androgens. Though not itself a 17-ketosteroid, it is degraded in the human body to appear in the urine as the biologically less active 17-ketosteroid, androstenedione, and the biologically inactive stereo-isomeric compound, etiocholanol-3- $\alpha$ -17-one. These, and the related neutral 17-ketosteroids, are regarded as androstane derivatives or  $C_{19}$  steroids since they have nineteen carbon atoms

in the typical steroid skeleton. The other important androgen found in the urine is dehydroisoandrosterone, which is also a 17-ketosteroid. Present evidence suggests that the latter has its origin chiefly from the adrenal cortex. Isoandrosterone, a weakly androgenic 17-ketosteroid, has also been recovered from human urine.

Other less important related steroids which have been isolated from normal urine are androstenone-17,  $\Delta^3$  androstadiene-17 one and etiocholandi-3 ( $\alpha$ ), 17.<sup>12</sup>

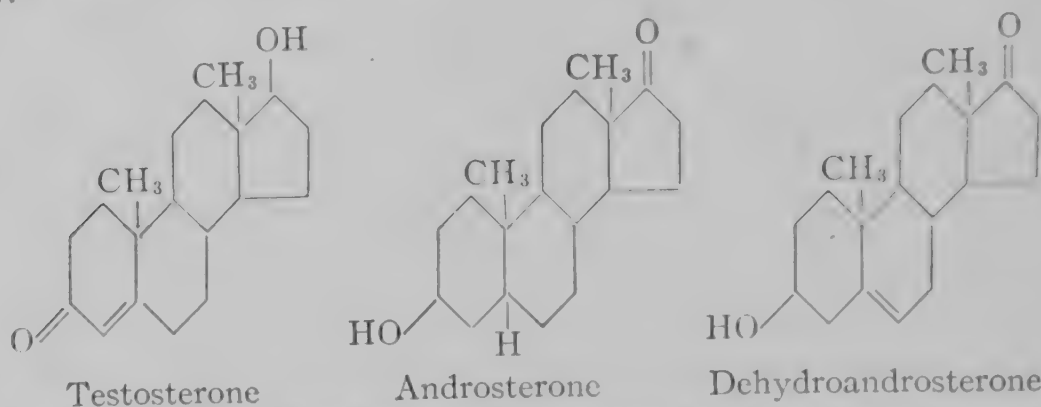


Fig. 185. Structural formulas of testosterone, androsterone and dehydroandrosterone. (Cantarrow and Trumper: Clinical Biochemistry.)

The 17-ketosteroids can be divided into those which are digitonin-precipitable (beta 17-ketosteroids) and those which are digitonin-nonprecipitable (alpha 17-ketosteroids). They may also be divided into alcoholic and nonalcoholic compounds. The chief 17-ketosteroids found in normal urine may be divided as follows:

- A. Alpha-17-ketosteroids (digitonin-precipitable)
  - 1. Androsterone
  - 2. Etiocholanol-3 alpha-one-17
- B. Beta-17-ketosteroids (digitonin-nonprecipitable)
  - 1. Dehydroisoandrosterone
  - 2. Isoandrosterone

## NORMAL PHYSIOLOGY OF THE ANDROGENS

Testosterone is apparently the chief, if not the only, androgen secreted by the testis. Little is known concerning its biogenesis except that it apparently is made in the interstitial cells of Leydig under gonadotrophic influence. It has been suggested that the adrenal cortex may furnish some of the precursors for testicular androgen, in addition to directly secreting androgenic materials.

Androgens appear in the blood, but in amounts too small to be readily detected. It is generally assumed that the androgens, like the estrogens, are inactivated by the liver, although the evidence on this score is not so complete as for the estrogens. Androgens have also been recovered from the bile, suggesting that they too may undergo an enterohepatic circulation.

The androgens and related 17-ketosteroids are excreted in the urine in a water-soluble conjugated form requiring preliminary acid hydrolysis before they can be extracted for biologic assay or chemical determination. Although the assay of biologically active androgens and the chemical determination of urinary

17-ketosteroids are not strictly comparable, for most chemical purposes the correlation between the two is sufficient to be of significance. Since a large part of the 17-ketosteroids is of adrenal origin, it is to be expected that factors influencing cortical function will be reflected in the androgen and 17-ketosteroid values. The relative simplicity of the latter determination has permitted more extensive investigation of such factors. It has been shown that even such physiologic factors as sleep and physical stresses will significantly influence the 17-ketosteroid excretion; while common colds, debilitation or systemic disease will markedly lower the excretion.

### BIOLOGIC ACTIONS OF THE ANDROGENS

Androgenic substances are concerned with the growth and function of the accessory reproductive organs, particularly the penis, prostate and seminal vesicles, as well as the development of the secondary sex characteristics, such as masculine hair distribution, beard growth, deepening of the voice and male type of somatic development. Testosterone tends favorably to influence the retention of sodium chloride and water in the body. Under certain circumstances its administration also favors the retention of nitrogen, creatine, potassium, inorganic phosphorus and sulfate; heat production is also increased. In boys the adolescent growth spurt and the subsequent closure of the epiphyses are likely due to the androgens. Like the estrogens, androgens tend to inhibit the secretion or liberation of certain pituitary hormones, particularly the gonadotrophins if administered in large dosage.

In biologic assays of androgens, use is made of the comb growth which occurs in capons or chicks after the local application of the hormone.

In addition to the functions described for the androgens, it is probable that the 17-ketosteroids of adrenal origin, particularly those which are not androgenic, may exert other physiologic and metabolic influences. There are at present no methods available by which these metabolic hormones of the adrenal cortex can be assayed readily for clinical purposes.

### BIO-ASSAY OF URINE FOR ANDROGENS AND 17-KETOSTEROIDS

It is not possible to isolate and chemically determine the individual androgens in urine collections available for chemical purposes. For this reason, bio-assay of urine extracts must be employed to determine the total biologic androgenic activity. The most accurate method is based upon stimulation of comb growth in the capon after the administration of extracts by injection or by direct application (inunction) to the comb for a number of days.<sup>7</sup> The results are expressed in terms of international units (I.U.), one international unit being equivalent to the activity of 0.1 mg. of androsterone. Methods based upon increased growth (weight) of the comb of the baby chick have also been described.

Although there has been considerable controversy concerning the reliability of the baby chick method, satisfactory results have been obtained if the procedure is carefully controlled.<sup>8-10</sup> This method is much more sensitive than the capon method and technically much easier to carry out. The normal values obtained with the baby chick method are about one-seventh those obtained

by the capon method when assayed against androsterone. A corresponding correction factor must, therefore, be introduced when comparing results obtained with these procedures.

Biologic assays based upon stimulation of the prostate or seminal vesicles of the castrate rodent are not very satisfactory since other "X" substances in the extracts may have a nonspecific augmenting effect.

17-KETOSTEROIDS. Colorimetric methods are used for the determination of 17-ketosteroids in hydrolyzed urine extracts. There is considerable controversy concerning the details in the technic for hydrolysis and the efficiency of various solvents for extraction.

For the determination of total natural 17-ketosteroids it is not necessary for clinical purposes to separate the ketosteroids with Girard's reagent before colorimetric assay unless fractionation of the extract into alpha and beta fractions is to be carried out.

For the colorimetric determination, the Zimmerman<sup>19</sup> reaction is used. This is based upon the intensity of the red color produced by 17-ketosteroids with m-dinitrobenzene in alkaline solution. The results are generally reported in terms of androsterone equivalents. Pincus<sup>10</sup> has developed a more specific colorimetric reaction which involves the development of a blue color with antimony trichloride. In the Pincus method dehydroisoandrosterone is only feebly reactive.

NORMAL VALUES FOR ANDROGENS

CHILDHOOD. Only small amounts of biologic androgenic activity can be demonstrated in the urine of children of both sexes before puberty. In boys six and one-half to ten years of age Koch found values of 0.7 to 2 international units per liter of urine, and in girls eight to ten years of age, values of 1.8 to 2 international units per liter. (One international unit is equivalent to 0.1 mg. of androsterone.) At puberty, values up to 20 international units may be found. The capon method for the bio-assay method was used.

TABLE 281  
ANDROGEN (BIOLOGIC ASSAY)  
(Cantarow and Trumper, 1945)<sup>3</sup>

	Urinary Excretion per 24 Hours in I.U.	
	Range	Average
Children (male and female) up to 10 years . . . . .	0.5- 2.0	
Young adult males . . . . .	30 -100	70
Young adult females . . . . .	30 -100	50

REPRODUCTIVE PERIOD. Young adult men and women usually excrete 30 to 100 international units of androgens daily, although ranges of 15 to 170 international units per liter have been reported. Normal women excrete almost as much androgen as do men. On the average, men excrete about 70 international units per twenty-four hours; women, about 50 international units. Even in the same person there appears marked variation in the day-to-day output, amount-

ing to as much as 100 per cent on two different three-day periods. The present consensus is that there are no true cyclic fluctuations in androgen values in either men or women such as occur in estrogen excretion in women. Because of the higher estrogen excretion in women the androgen:estrogen ratio in men is two to five times that in women.

**PREGNANCY.** Androgen values during pregnancy fall within the normal range for nonpregnant women. Several observers have reported somewhat lower values. Dingemanse and his co-workers<sup>1</sup> found excretion levels of 8 to 30 units per liter between the sixth and eighth months. Hain<sup>2</sup> found excretion levels of 10 to 30 international units per twenty-four hours in patients from the fourth to ninth months of gestation. There was no significant correlation between androgen excretion and the sex of the fetus.

**CLIMACTERIC.** There is a gradual and moderate drop of androgens in older men, which, in some cases, may begin after about the forty-fifth year, but in others not for another five to ten years.

In menopausal or postmenopausal women, biologic androgen values may be normal or diminished.

NORMAL VALUES FOR 17-KETOSTEROIDS

The values for 17-ketosteroids generally refer to the "total neutral 17-ketosteroids" in the crude neutral extract in terms of equivalent of andros-

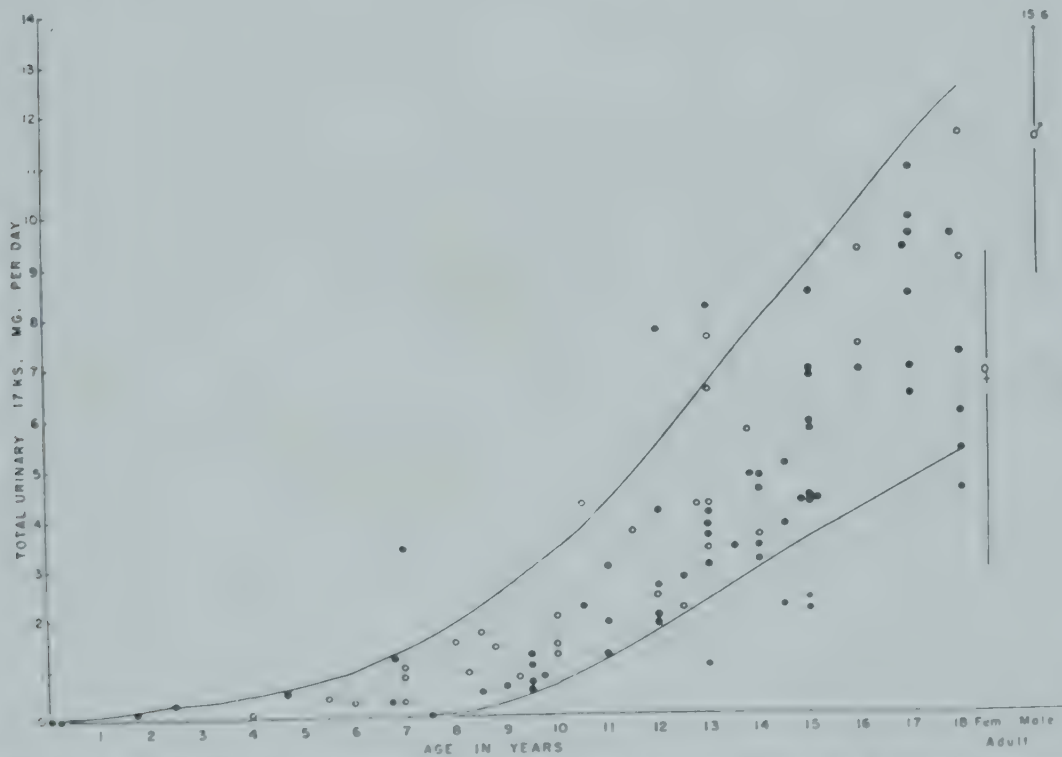


Fig. 186. Excretion of 17-ketosteroids by normal persons. The black dots indicate values for boys; the circles, for girls. (Talbot, N. J., Berman, A. M., Rodriguez, P. M., and MacLachlan, E. A.: *Am. J. Dis. Child.*, vol. 65.)

terone. For the purified ketonic neutral fraction the values are about 20 per cent lower.

CHILDHOOD. Small amounts of 17-ketosteroids are found in the urine of young children of both sexes from about the age of three years on. Up to the age of six years the values are usually below 1 mg., occasionally ranging up to 2 mg. There is a slow increase in the 17-ketosteroid values up to eight years of age in both sexes.<sup>9</sup> From the ages of eight to eleven years the increase is more rapid. The rise tends to be more rapid in boys than in girls. Another spurt in 17-ketosteroid excretion occurs at about the age of eleven years in boys, coinciding with a sudden acceleration in the growth of the testes and the appearance of the first signs of the secondary sex characteristics. In girls beyond eleven years of age the 17-ketosteroid excretion is more gradual since it probably comes entirely from the growing adrenal. The values continue to rise during the pubertal years to reach adult levels at from fourteen to eighteen years of age (Fig. 186 and Table 282).

TABLE 282  
AVERAGE OUTPUT OF 17-KETOSTEROID PER DAY BY NORMAL PERSONS OF VARIOUS AGES  
(Talbot et al., 1943)<sup>15</sup>

Age, Years	17-Ketosteroid Output, Mg./24 hrs.	Age, Years	17-Ketosteroid Output, Mg./24 hrs.
3.....	0.15	12.....	3.4
4.....	0.3	13.....	4.3
5.....	0.4	14.....	5.3
6.....	0.5	15.....	6.3
7.....	0.65	16.....	7.2
8.....	0.95	17.....	8.1
9.....	1.4	Adult women.....	6.8
10.....	1.9	Adult men.....	11.0
11.....	2.6		

REPRODUCTIVE PERIOD. In normal mature persons there is a considerable overlapping of normal values in the two sexes, but the values tend to average about one-third higher in men than in women. The normal range given by different workers varies somewhat. Table 283 gives representative examples.

TABLE 283  
17-KETOSTEROID VALUES IN NORMAL MATURE PERSONS (MG. EQUIVALENT OF ANDROSTERONE)

	Men		Women		Investigator
	Range	Average	Range	Average	
	6-15	.....	6.9-12.6	.....	Callow (1939)
	8.1-22.6	13.8	5.1-14.2	9	Fraser et al. (1941)
Crude neutral fraction.....	7-27	.....	5-18	.....	Pincus (1943)
Ketonic neutral fraction.....	5-23	.....	3.5-15	.....	Pincus (1943)
	7-20	.....	5-15	.....	Rakoff (1945)
	12.3-18.5	15	6.5-17.4	10.2	Talbot (1942)

Although there are considerable day-to-day fluctuations in 17-ketosteroid values, no true cyclic fluctuations occur in women or men. A definite diurnal

hythm in both men and women apparently exists in which the lowest values are obtained during the period of sleep.

TABLE 284  
DAY AND NIGHT 17-KETOSTEROID VALUES  
(Pincus, 1943)<sup>11</sup>

Subject	Number of 24-Hour Periods	17-Ketosteroid Titer, Mg. per Hour	
		Night	Day
.....	7	0.362	0.489
.....	6	0.409	0.523
.....	6	0.416	0.460
.....	9	0.462	0.557
.....	5	0.504	0.627
.....	7	0.574	0.882
.....	8	0.630	0.948

TABLE 285  
AVERAGE EXCRETION OF ALPHA, BETA AND TOTAL NEUTRAL KETOSTEROIDS BY NORMAL SUBJECTS\*  
(Talbot et al., 1940)<sup>16</sup>

Type of Subject	No. of Cases	Average Alpha Neutral Ketosteroids, Mg. per 24 Hours	Beta Neutral Ketosteroids, Mg. per 24 Hours		Total Neutral Ketosteroids, Mg. per 24 Hours	
			Average	Range	Average	Range
Children:						
4 to 7 years.....	5	1.2	0.1	0.0-0.2	1.3	0.8- 2.6
7 to 12 years.....	10	3.7	0.3	0.0-0.5	4.0	1.8- 5.0
12 to 15 years.....	7	7.5	0.7	0.0-2.7	8.2	5.0-11.3
Women, 15 + years.....	9	9.1	1.1	0.0-2.5	10.2	6.5-17.4
Men, 15 + years.....	5	13.8	1.2	0.0-1.8	15.0	12.3-18.5
Women, 4 to 7 months pregnant..	4	13.2	1.9	0.0-4.0	15.1	10.8-20.4

\* Forty-nine determinations were made on 40 subjects who were hospital staff members or patients presenting no obvious evidence of endocrine disorder.

The cases studied showing high night titers appear to be associated with high day values, and vice versa. This is of significance in that, for clinical purposes, it frequently is convenient to make assays on twelve-hour specimens collected at night. The maximum day values tend to occur in specimens taken during the morning hours. It has already been pointed out that physical and mental stress and strain often increase the 17-ketosteroid excretion, while many

nonendocrine conditions, malnutrition, anemia, infections and gastrointestinal disease may lower the 17-ketosteroid excretion.

**FRACTIONATION OF 17-KETOSTEROIDS.** It has been pointed out that although identification of specific urinary 17-ketosteroids requires methods of chemical isolation which are not practicable for routine work, the separation of various groups may be effected. The separation into alpha and beta 17-ketosteroids is of value in certain endocrine dysfunctions, particularly in diseases of the adrenal cortex. Normally, the beta 17-ketosteroids seldom constitute more than 15 per cent, and often only 2 to 3 per cent, of the total.

The alcoholic (hydroxylated) ketosteroids constitute 50 to 85 per cent of the total.

**PREGNANCY.** The 17-ketosteroid values during normal pregnancy generally fall within the normal range for nonpregnant women. Fraser and his co-workers found moderately low values in some cases of normal pregnancy, but normal values in most instances (the range for their patients was 4.7 to 15.4). On the other hand, Burrows and his associates<sup>1</sup> noted moderately increased values in patients tested during the first trimester of pregnancy, with the higher values occurring when the fetus was male. These findings remain to be confirmed.

**CLIMACTERIC.** In menopausal women the values for 17-ketosteroids generally fall within the normal range or may be diminished moderately; occasionally, moderately increased values are encountered, thought to be indicative of increased functional activity of the adrenal cortex. Rakoff<sup>13</sup> reports values ranging from 3 to 18 mg. per twenty-four hours for menopausal women.

In men the 17-ketosteroid values often begin to diminish in the late forties, but usually remain within the normal adult range well into the next decade. Values below 5 mg. are often obtained in elderly men.

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## Chapter 58

### ESTROGENS

**SOURCES.** In the human female, estrogens are produced primarily by the ovary, although the adrenal cortex is also a source for some steroids which have estrogenic activity. In the ovary, estrogens are secreted chiefly by the granulosa cells of the follicles, but also by the thecal and interstitial cells and by the cells of the corpus luteum (which are modified granulosa cells). The estrogen elaborated by the ovary is probably mostly alpha-estradiol, but there is also some evidence that estrone may be present in follicular fluid. Doisy<sup>7</sup> has estimated that during a normal menstrual cycle the ovary secretes the equivalent of 0.1 mg. of estrone. During pregnancy, estrogens are secreted in rapidly increasing amounts by the placenta, probably by interstitial cells and not by the chorionic cells which produce the gonadotropic hormone. Estriol makes up a large fraction of the estrogen produced by the placenta, but estrone and estradiol are also present. In late pregnancy 12 to 50 mg. of estrogenic material may be secreted per day.<sup>15</sup>

In men it has been postulated, but not proved, that the testes as well as the adrenal cortex secrete estrogens. This is supported by the observation that in hypogonad men estrogen excretion is diminished, but not entirely absent.

### BIOCHEMISTRY OF THE NATURAL ESTROGENS

The estrogens are steroids related chemically to cholesterol, bile acids, vitamin D, cardiac glycosides and hemolytic saponins. Their structure is built on the cyclopentenophenanthrene nucleus (Fig. 187). The parent saturated hydrocarbon is estrane. In estrone (ketohydroxyestrin; theelin), the first ring A is unsaturated, with a hydroxyl group at carbon atom 3 and oxygen at carbon atom 17. Estradiol (dihydroxyestrin) has hydroxyl groups at positions 3 and 17. Estriol (trihydroxyestrin; theelol) has three hydroxyl groups at positions 3, 16 and 17. The natural estrogens are soluble in ether, alcohol, acetone and many oils, but not in petroleum ether. They are practically insoluble in water, but owing to their phenolic nature they are quite soluble in aqueous alkali, permitting separation from other sex hormones which are nonphenolic. The ketonic estrogen, estrone, may be separated from the nonketonic estrogens alpha-estradiol and estriol by means of the Girard reagent, while estriol and estradiol can be partitioned by their relative solubility between 0.3 M  $\text{Na}_2\text{CO}_3$  and benzene. The natural estrogens give the color reactions obtained with simple phenols with Millon's reagent, diazotized aromatic amines and Folin's phenol reagent. Kober<sup>11</sup> showed that under certain conditions estrogens react with a mixture of phenol and sulfuric acid to give a red color, the intensity of which can be used for quantitative determinations of purified extracts.

## BIOLOGIC ACTIONS OF THE ESTROGENS IN THE HUMAN

The estrogens induce or influence many physiologic responses. The most striking of these is proliferation of the epithelium of the müllerian system, particularly the vaginal epithelium and endometrium. They also produce growth of the myometrium, and duct system of the breast and nipple. Suppression of certain anterior pituitary hormones, particularly the follicle-stimulating hormone and prolactin, follows the administration of large doses of estrogens. Estrogens also favor a retention of salt and water under certain conditions. In the male, estrogens, in sufficiently large dosage, inhibit testicular function and produce the physiologic effects of castration, probably through their action on the pituitary.

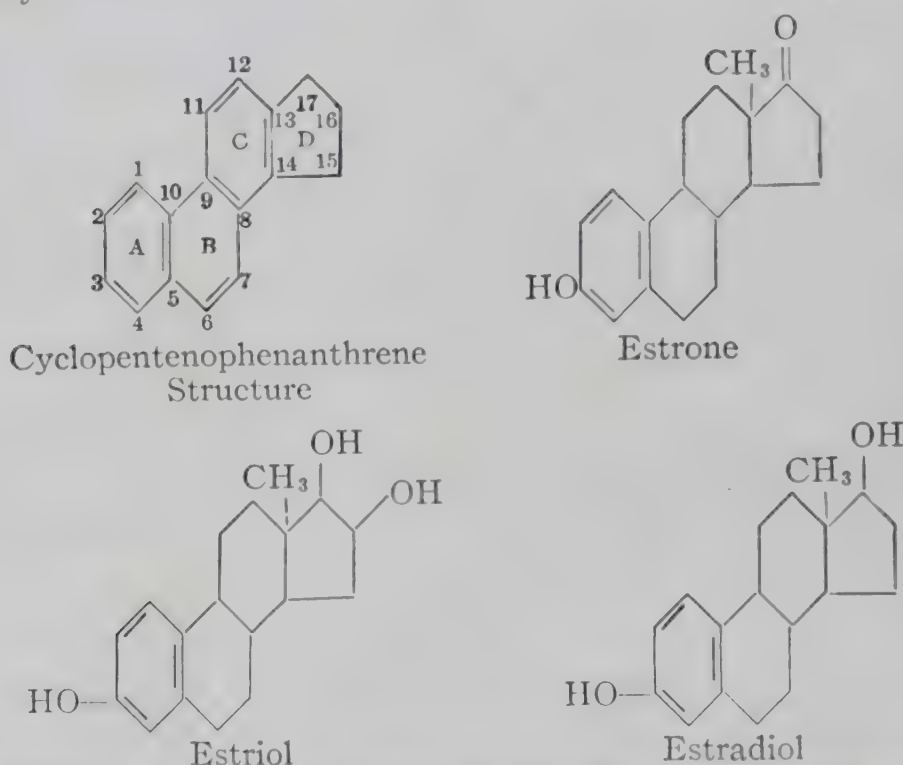


Fig. 187. Structural formulas of cyclopentenophenanthrene, estrone, estriol and estradiol. (Cantarow and Trumper: Clinical Biochemistry.)

## NORMAL PHYSIOLOGY OF ESTROGENS

The secretion of estrogens by the ovary is stimulated by the gonadotrophic hormones. Present evidence indicates that follicle-stimulating hormone alone does not stimulate estrogen production. It is therefore probable that even during the follicular phase sufficient luteinizing hormone is present to stimulate estrogen production. During the active corpus luteum phase, estrogens are produced by the luteal cells under the influence of the luteinizing hormone, possibly in synergism with a luteotrophic hormone. The ovarian estrogens enter the systemic circulation and are present chiefly in the free form, although some may be bound to protein. The chemical form of the blood estrogen is not known. The estrogens reach the liver and are rapidly inactivated in that organ, but are then apparently reactivated and appear in the bile, subsequently undergoing

enterohepatic circulation during which the bulk of the hormone is probably gradually metabolized in the liver, small amounts being released into the systemic circulation for many days.<sup>4</sup>

THE FEMALE SEX ENDOCRINE CYCLE

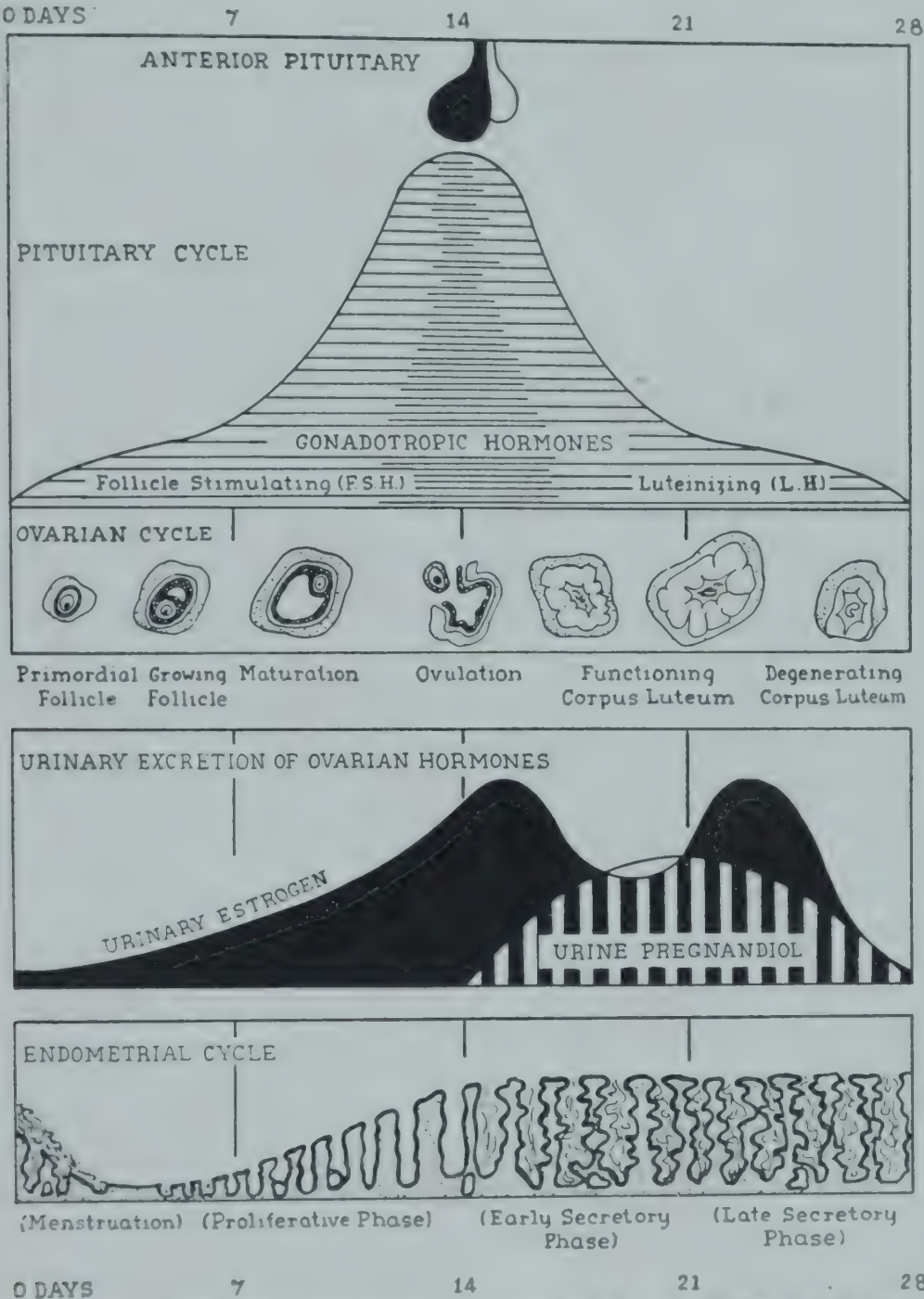


Fig. 188. The female sex endocrine cycle. (Courtesy of Dr. A. E. Rakoff. Cantarow and Trumper: Clinical Biochemistry.)

In the human being it appears that alpha-estradiol and estrone can be converted one to the other and that both can be excreted as estriol. In some species a functional uterus seems to be essential for the conversion of estrone

to estriol, but apparently this is not a prerequisite in the human. There is some evidence that progesterone prevents the excessive destruction of estrogens and facilitates a conversion of estrone to estriol. Further extensive destruction of the estrogens to other compounds devoid of biologic activity proceeds, but the mechanism and the metabolites are not known. The remaining estrogens are finally excreted by the kidneys, chiefly in a conjugated form as water-soluble substances, mainly glucuronidates, which can be freed by acid hydrolysis. It is estimated that only 5 to 10 per cent of the endogenous estrogen can be recovered as biologically active hormone from the urine.

During the early weeks of pregnancy, estrogens continue to be formed by the corpus luteum of pregnancy, but are gradually replaced by increasing amounts of estrogen produced by the placenta. In the urine, estriol predominates throughout gestation. This may be accounted for by the conversion of alpha-estradiol and estrone to estriol, as well as the endogenous production of estriol itself. During pregnancy the rate of destruction of estriol is apparently low. Almost all the estrogen is present in conjugated form until several weeks before the onset of labor, at which time there is a fall in total urinary estrogens, but an increase in free hormone.

Estrogens are usually present in such small amounts in the blood and urine that it is not possible to isolate the specific estrogens present for quantitative chemical determination. In late pregnancy where the amounts of estrogens excreted are high, applications of colorimetric methods have been made by Kober,<sup>11</sup> Cohen and Marrian,<sup>5</sup> Venning and his co-workers,<sup>20</sup> and Bachman.<sup>2</sup>

The most generally used procedure for determining estrogens is by biologic assay of blood or urine or their extracts. In women, estrogenic function can often be evaluated in a semiquantitative fashion by its effect on the vaginal epithelium as determined by cytologic study of the vaginal secretion. Because of the ease and rapidity with which this test can be performed and the satisfactory information which it affords for a large number of cases, it has replaced the more complicated biologic assay to a considerable extent.

### BIO-ASSAY OF ESTROGENS

For the assay of estrogens some modification of the Allen-Doisy<sup>1</sup> procedure is commonly used, in which the material or extract is injected into castrated adult mice or rats and the degree of proliferation of the vaginal epithelium is determined from vaginal smears. Minimal responses can be determined from histologic study of the vaginal epithelium, as in the technic of Fluhmann.<sup>8</sup> The uterine weight response in infantile animals has also been used as an assay method.

Although these methods are capable of detecting small amounts of estrogens, minor alterations in detail of technic may result in wide degrees of variation in results, so that findings from different laboratories are often not comparable. Findings are best interpreted on the basis of the normal standards of the individual laboratory; details of the technic employed should accompany reported values.

Another great source of confusion arises from the fact that estrogen activity

may be expressed either in terms of mouse units (M.U.), rat units (R.U.) or international units (I.U.). Moreover, these units cannot be accurately interconverted if a mixture of various estrogens is present. For estrone, which is the chief estrogen in the urine of nonpregnant subjects, 1 rat unit is usually equivalent to about 10 mouse units, but 1 mouse unit may equal 1 to 5 international units, depending upon the method of assay. Similarly, estradiol may vary in potency from two to twelve times that of estrone, depending upon the method and technic of assay, while estriol has been reported to vary from one to less than one-one hundredth the potency of estrone. The following international standards have been established on the basis of weight of the crystalline hormones.

1. *Estrone*: 1 international unit (I.U.) is equivalent to 0.0001 mg. (0.1 gamma).

2. *Estradiol benzoate*: 1 international benzoate unit (I.B.U.) is equivalent to 0.0001 mg. (0.1 gamma). This standard is of use only for pharmaceutical products in which estradiol benzoate preparations may be employed.

In making estrogen assays of urine or serum, the whole untreated material may be injected if the hormone is known to be present entirely in a free form, but if it largely is in the blood and bile, or if only the free estrogen value is desired, provided its concentration is sufficient to be detected in volumes small enough to be injected into the animals. On the other hand, if the hormone is present largely in a conjugated form as it usually occurs in the urine, preliminary hydrolysis is necessary, then extraction of the hormone and its concentration in a small volume of oil for injection. Hydrolysis procedures vary widely in the degree of liberation and destruction of hormone which occurs, with consequent variation in results. The degree of purification of the extract and its separation into various estrogen fractions depends upon the type of information that is desired from the assay. In those special instances in which fractionation is desired, the separation into ketonic (estrone) and nonketonic estrogens (estradiol and estriol) is made with Girard's reagent, and then the latter two estrogens may be further separated by partitioning between benzene and 0.3 molar of sodium carbonate, as described by Doisy.<sup>7</sup>

### NORMAL ESTROGEN VALUES BY BIO-ASSAY

**CHILDHOOD.** Small amounts of estrogen are present in the urine of even very young children. In children from the ages of three to seven years, Nathan, Towne and Aub<sup>14</sup> found values up to 10 international units of estrone in twenty-four-hour urine collections in both boys and girls. The titers showed a distinct rise after the age of seven years, but a striking sex difference does not become apparent until the age of nine or ten years, when the excretion role in males increases and becomes enormously accelerated after the age of eleven years. Distinct cyclic changes were noted in some instances as much as a year and a half before the menarche. In boys only a slow, gradual rise in estrogens is observed through childhood and the pubertal years.

**REPRODUCTIVE PERIOD (FEMALE).** Throughout the menstrual cycle estrogens are excreted in readily determinable amounts, and at certain phases of

the cycle sufficient free hormone is present in the blood to be found by bio-assay. There is a cyclic excretion in estrogens during the normal menstrual cycle. Low levels are present during the first week of the cycle and gradually increase as follicular activity is stimulated by the gonadotrophins to reach a peak at the ovulatory phase. Smith and his co-workers<sup>19</sup> found this peak to occur after ovulation or twelve days before menstruation, while D'Amour<sup>2</sup> noted such a rise in the preovulatory phase. The level then often drops for several days, to rise again as corpus luteum function becomes well established. A second

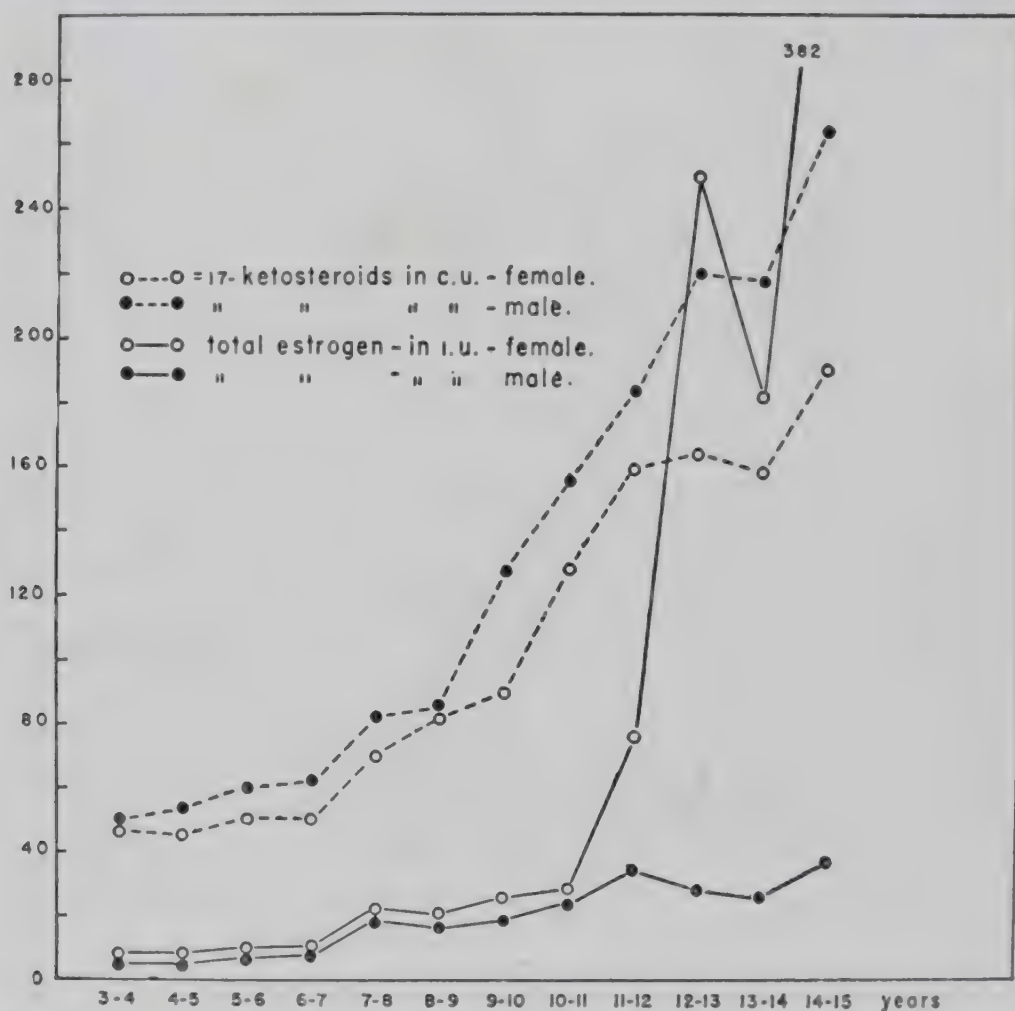


Fig. 189. Summarizing chart of all determinations of excretion of 17-ketosteroids and estrogens in girls and boys of different ages. Consecutive assays are averaged and used as a single determination (estrogens reported in international units, 17-ketosteroids in "color-units"). (Nathanson, I. T., Towne, L. E., and Aub, J. C.: *Endocrinology*, vol. 28.)

peak in estrogen excretion is reached in the third week of the cycle, usually from seven to four days before the next menstruation. The two peaks are of approximately the same magnitude, but in individual cases either the first or second peak may be higher. The second peak is followed by a rapid drop or "estrogen withdrawal" to reach a low level in the immediate premenstrual phase. There is considerable variation in the shape and height of the curves in different persons and from month-to-month in the same person. Table 286 gives average excretion values for typical phases of the menstrual cycle.

More detailed study of the physiology of the estrogens during a normal menstrual cycle involves the fractionation of the estrogens. Relatively few such studies have been made. Table 287 shows total and fractional values on specimens collected at representative intervals during a normal twenty-eight day menstrual cycle.

TABLE 286  
ESTROGEN VALUES IN THE URINE AND SERUM  
(Rakoff, 1945)<sup>17</sup>

<i>Estrogens in</i>	<i>Female, Days of the Menstrual Cycle</i>				<i>Meno- pausal Women</i>	<i>Male</i>
	7	14	21	28		
Urine (24 hours)*						
Range.....	65-160	160-660	160-660	30-110	10-65	25-100
Average.....	110	330	500	65	Under 65	50
Serum†.....	Traces-6	3-9	3-9	0-3	0-traces	

\* In international units per 24 hours, conversion to mouse units or rat units depends upon the method and technic employed by the individual laboratory.  
† Mouse units per 100 ml., employing the technic of Fluhmann.<sup>8</sup>

BLOOD VALUES. In the nonpregnant woman, blood estrogen assays are not so reliable as urinary assays, owing to the small amount of hormone present. Indeed, only at the midcycle and premenstrual peaks can blood estrogen be regularly demonstrated. For average findings for serum estrogen employing the Fluhmann procedure, see Table 286.

TABLE 287  
ESTROGEN EXCRETION IN URINE PER 24 HOURS (INTERNATIONAL UNITS)  
(Smith et al., 1943)<sup>19</sup>

<i>Days of Cycle</i>	<i>Total Estrogen</i>	<i>Per Cent Estradiol</i>	<i>Per Cent Estrone</i>	<i>Per Cent Estriol</i>
-3.....	100	67	0	33
-8.....	215	49	18	33
-15.....	530	30	20	50
-21.....	615	34	23	43
-28.....	100	45	20	35

CLIMACTERIC. As the menopausal period is approached, estrogen excretion gradually falls and the cyclic fluctuations become less and less marked until a constant daily low level of excretion is reached. It is the withdrawal of cycling rather than the diminished estrogen excretion which probably results in the cessation of bleeding. In the menopausal period estrogen excretion values generally range from about 10 to 65 international units. Even ten years after

the cessation of the flow it is possible to recover minimal amounts of estrogen from the urine, but probably most of this is of adrenal rather than ovarian origin.

PREGNANCY. During pregnancy there is a progressive increase in the estrogen titers in the blood and urine, to reach highest values near term.

BLOOD. During the first trimester the estrogen value in the blood rises only slowly and indeed is not appreciably higher than may be found in the peak levels of some nonpregnant women. In the determinations by Goldberger and Frank\* it was not until the seventeenth week that the upper limit of nonpregnancy levels was exceeded. Certain pregnancy tests, such as the Mazer-Hoffman test, have been based upon the blood estrogen rise, but the much earlier and greater increase in gonadotrophins is more satisfactory for this purpose. After the twentieth week the blood estrogen curve rises rather rapidly to near term, when values of 600 to 1500 international units, or occasionally even higher, may be found. Although the urine estrogen values may fall in the last two weeks of gestation, the blood estrogens during this period tend to remain fairly stable. It has been demonstrated that prolonged acid hydrolysis may result in values 25 to 50 per cent higher than those for free estrogen, the additional estrogen being in a combined form, probably bound to protein.

TABLE 288  
SERUM ESTROGEN VALUES IN PREGNANCY\*  
(Cantarow and Trumper, 1945)<sup>3</sup>

Weeks of Amenorrhea	Serum Estrogens I.U./100 ML.	
	Range	Average
2.....	15- 80	30
4.....	15-100	40
8.....	30-125	60
12.....	45-165	80
16.....	80-200	125
20.....	165-250	165
24.....	165-330	250
28.....	100-400	330
32.....	250-600	400
36.....	330-750	500
40.....	330-1500	600

\* In this assay 1 mouse unit is approximately equivalent to 5 international units.

Almost immediately after the delivery of the placenta the estrogen concentration in the blood begins to decrease and within three to four days reaches nonpregnancy levels.

URINE. The total estrogen activity of the urine increases progressively throughout pregnancy to reach a maximum about two weeks before term. Within two weeks after the first missed period a distinct increase in total estrogen can be detected by bio-assay, and at eight weeks of amenorrhea values up to 1000 international units per twenty-four hours are commonly obtained. The total estrogen concentration at the peak near term may range from 50,000 to 100,000 international units, or even more, per twenty-four hours. The true

TABLE 289  
NORMAL PREGNANCY  
(Smith and Smith, 1940)<sup>18</sup>

Weeks Pregnant	Urine per 24 Hour Excretion					
	Estrone		Estradiol		Estriol	
	R.U.	Mg.	R.U.	Mg.	R.U.	Mg.
2	50	0.033	450	0.0225	1000	0.5
3	250	0.166	1000	0.05	4000	2.0
4	670	0.445	1330	0.066	8000	4.0
5	700	0.465	2000	0.10	15000	7.5
6	400	0.267	1330	0.066	20000	10.0
7	1330	0.89	1330	0.066	20000	10.0
8	400	0.267	1200	0.06	20000	10.0
9	1000	0.667	1500	0.075	22500	11.1
10	330	0.22	1000	0.05	25000	12.5
11	1000	0.667	1000	0.05	53000	26.5
12	670	0.45	1330	0.066	60000	30.0
13	0	...	400	0.02	20000	10.0

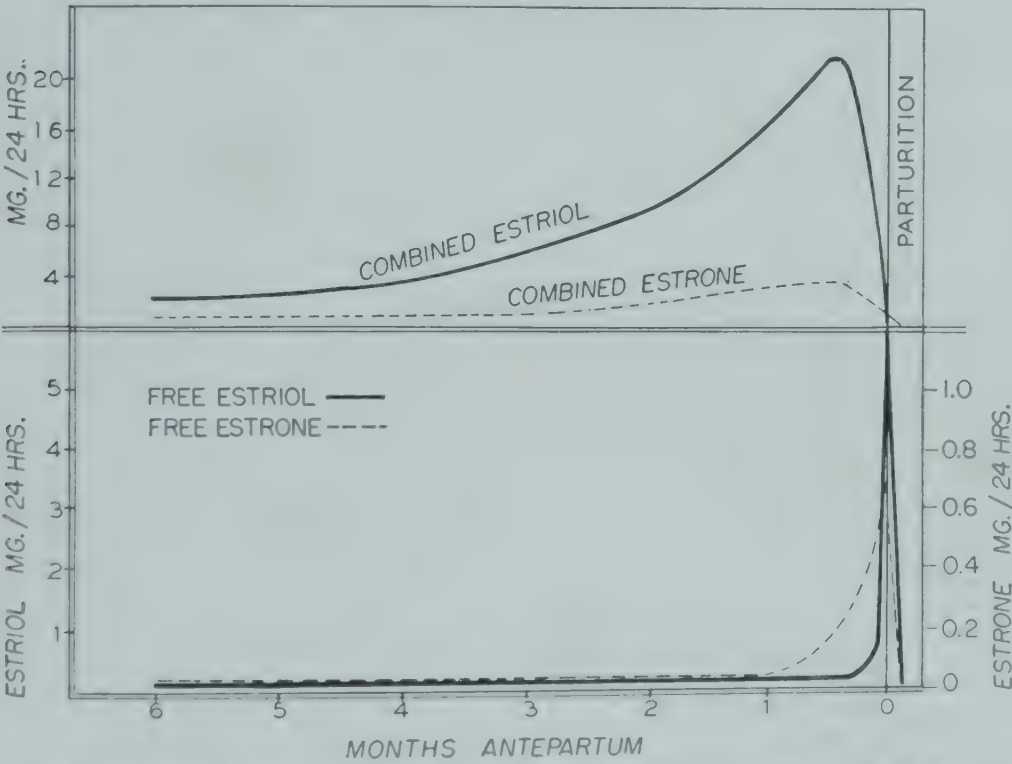


Fig. 190. Changes in the conjugation of urinary estrogens during late pregnancy and labor. (Modified from Cohen, Marrian and Watson. Hamblen, E. C.: Endocrinology of Woman, Charles C Thomas.)

potency is difficult to evaluate in biologic terms because there is a mixture of estrone, estradiol and estriol, each of which has different potencies when assayed by different methods. The greatest rise occurs in the estriol fraction.

About two weeks before the onset of labor a fall occurs in the total urinary estrogens which is thought to be due to a gradually decreasing rate of production and conversion and some increase in the rate of destruction of the placental steroids. During these periods there is also rapid conversion of combined to free estrogen. Before this stage the estrogens are excreted almost entirely (up to 99 per cent) in a conjugated form; at the time of labor the free estrogen may exceed the combined form (Fig. 190).

**MALE.** Estrogens can be demonstrated in the urine of normal men in amounts usually ranging from about 25 to 100 international units. Cycle increases in estrogen such as are noted in women do not occur in men, although day-to-day variations have been observed.<sup>21</sup> It is believed that the estrogens in male urine are chiefly of adrenal origin, although this is not certain, since the urinary excretion of estrogens is lowered in castrates and hypogonadal males.<sup>12</sup> All three of the natural estrogens have been found in male urine. The determination of urinary estrogens in the male is of limited value.

### VAGINAL SMEAR METHOD FOR THE DETERMINATION OF ESTROGEN EFFECT AND OVARIAN FUNCTION

The vaginal smear method is based upon the fact that proliferation of the vaginal epithelium is primarily controlled by estrogenic hormone so that the thickness of the epithelium serves as an indication of estrogen function. It is possible to correlate the degree of proliferation of the vaginal epithelium from cytologic examination of the superficial vaginal cells which have been des-



Fig. 191. Postmenstrual smear. Large noncornified cells. Little evidence of estrogen effect.\*



Fig. 192. Early proliferative phase. Noncornified cells, leukocytes and mucus. Slight estrogen effect.\*

quamated. Moreover, by special staining methods it is also possible to tell the degree of superficial cornification which has occurred; this gives further evidence of estrogen function since, after maximum proliferation of the vaginal epithelium has been reached, cornification of the surface layer occurs. In the presence of progesterone the effect of estrogen on the vaginal epithelium is to some extent neutralized, with resulting regressive changes in the morphology

\* Courtesy of Ortho Products, Inc.



Fig. 193. Preovulatory phase, showing some cornified, some leukocytes and noncornified

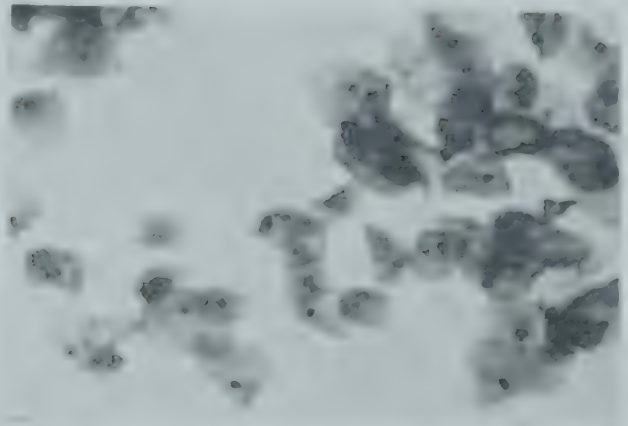


Fig. 194. Ovulatory phase. Desquamation and aggregation of cornified cells. Height of estrogen effect.\*

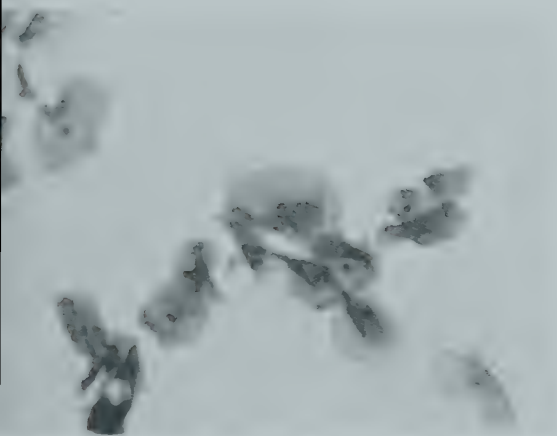


Fig. 195. Postovulatory phase. Large folded cells with pyknotic nuclei. Early corniteum effect.\*

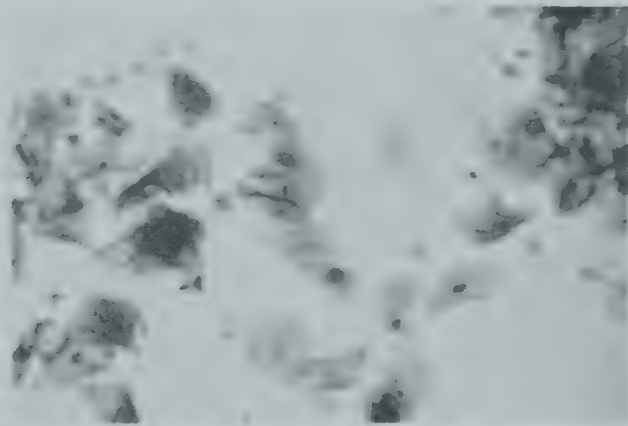


Fig. 196. Early premenstrual phase. Abundance of leukocytes and mucus, in addition to folded cells. Typical progesterone effect.\*



Fig. 197. Late premenstrual phase, showing degeneration of epithelial cells, mucus and leukocytes.\*

\* Courtesy of Ortho Products, Inc.

and staining characteristics of the superficial cells. In this way it is also possible to determine to some extent the presence of progesterone by daily examination of the vaginal smears. It must be emphasized, however, that the progesterone changes are not specific and can be imitated by any factor which causes withdrawal or neutralization of estrogens.

**MARKED ESTROGEN DEFICIENCY.** All the cells are from the basal layer of the vagina. Many of the cells are from the deepest layer and have hyperchromatic nuclei. Many cells show mitotic activity. Leukocytes are numerous, often markedly excessive because of an associated atrophic vaginitis. Mucus is usually present, and frequently there are histiocytes. In the presence of an inflammatory reaction a few of the basal layer cells may be acidophilic in staining or even appear to be "cornified." This type of smear is seen in many castrates, in senile women, but also in occasional menopausal women with a severe menopausal syndrome; it may also occur in younger amenorrheic women with marked ovarian deficiencies.

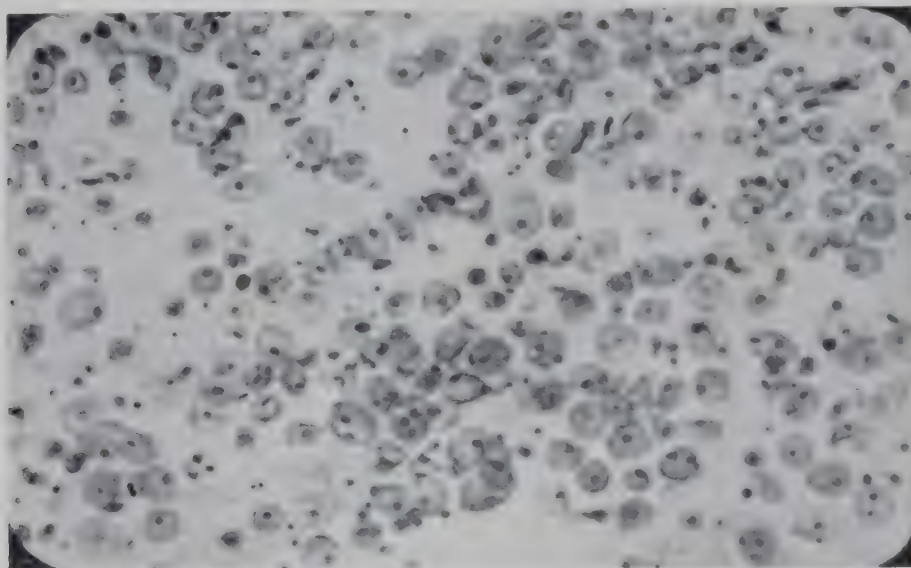


Fig. 198. Marked estrogen deficiency, showing the large numbers of round and ovoid basophilic cells from the basal vaginal layers, and also many leukocytes. (Rakoff, A. E.: *Progress in Gynecology*, Grune and Stratton, Inc.)

**MODERATE ESTROGEN DEFICIENCY.** The majority of cells are from the basal layers, but there are also some cells from the intermediate layer or even an occasional basophilic squamous cell of the superficial variety. Leukocytes are present in varying numbers, and mucus is plentiful. This is the commonest type of smear seen in menopausal and postmenopausal patients, or younger women with long-standing ovarian deficiencies.

**SLIGHT ESTROGEN DEFICIENCY.** The majority of cells are of the "intermediate" or transitional variety, often with some from the superficial layer which are of basophilic staining reaction. Moderate numbers of cells from the basal layer are interspersed. There is usually a moderate number of leukocytes and some mucus. In the mild menopausal syndrome or in older women without obvious menopausal symptoms this type of smear is commonly seen. In young women this degree of deficiency is usually associated with amenorrhea, hypomenorrhea or oligomenorrhea.

**MODERATE ESTROGEN EFFECT.** The majority of cells are basophilic stained, but many take an intermediate (lavender) stain, and some are acidophilic. Many of the acidophilic cells show markedly pyknotic or fragmented nuclei or complete cornification. Mucus stains lightly. This type of smear is normally seen in the late follicular and preovulative phases.

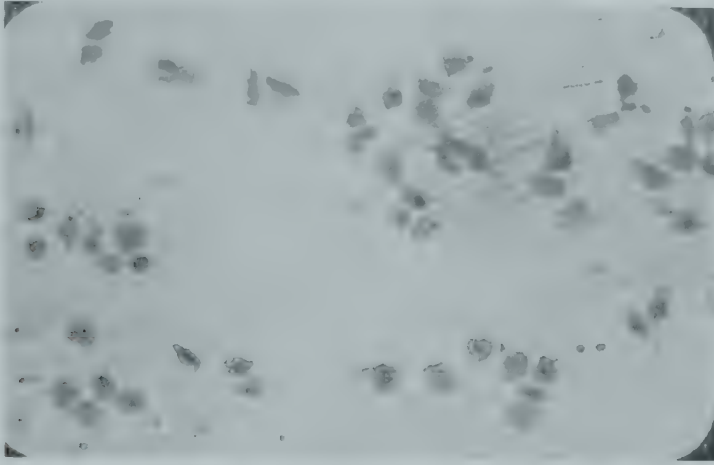


Fig. 199. Moderate estrogen deficiency, characterized by many cells from the basal layers and others from the intermediate layer, with leukocytes and mucus. (Rakoff, A. E.: *Progress in Gynecology*, Grune and Stratton, Inc.)

**MARKED ESTROGEN EFFECT.** Almost all the cells are acidophilic, some intensely so. Many of the cells show markedly small and dense or fragmented nuclei, and there are occasional completely cornified cells with no nuclei. Usually mucus hardly stains, and leukocytes are few unless there is an associated infection. Some of the cells may show some curling of the edges or folding.

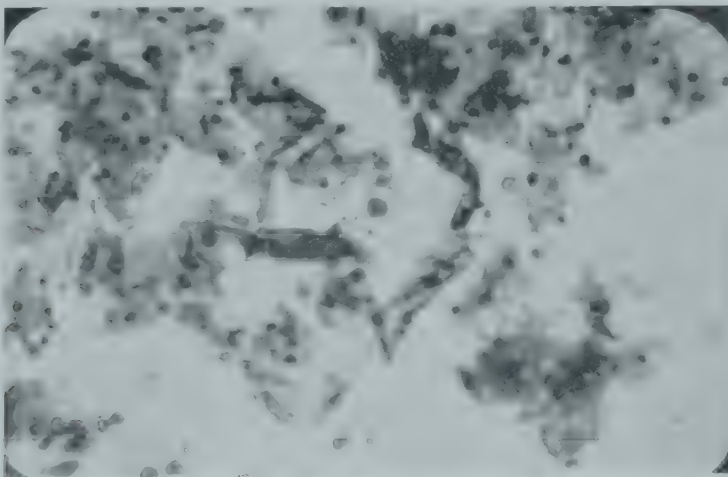


Fig. 200. Showing marked folding and twisting of the cells, many being of the navicular type. (Rakoff, A. E.: *Progress in Gynecology*, Grune and Stratton, Inc.)

Normally this type of smear is seen in the ovulative or postovulative phase. Patients receiving full estrogenic therapy also have this type of smear.

**ESTROGEN EFFECT WITH REGRESSION.** When the peak of full estrogenic effect has passed, there is a tendency for the cells to become folded, to lose their bright acidophilic staining and often to undergo cytolysis or mucification.

This change may occur due to the withdrawal of estrogenic hormone or if the estrogen is opposed by progesterone. From a single smear, therefore, one cannot determine with complete assurance that the "regressive" effect indicates the presence of progesterone and, therefore, an active corpus luteum. From smears taken daily it usually is possible to determine normal corpus luteum effect, since the regression progresses in an orderly fashion to marked mucification over a period of fourteen days. Regression due to fall in estrogen alone is more abrupt and does not show the same sequence.

**VAGINAL SMEAR IN PREGNANCY.** During pregnancy there is a progressive increase in both estrogen and progesterone which leads to further thickening of the vaginal mucosa, particularly the intermediate layer, and increased desquamation of the superficial layer. After the first two to four weeks of gestation the number of acidophilic cells decreases and the smear shows aggregates of folded basophilic cells from the superficial layer and the underlying intraepithelial zone of cornification. Many of the latter cells are of navicular shape with rather elongated nuclei; these have in fact been termed "pregnancy" cells. To the experienced observer this cytologic picture will suggest pregnancy.

If abortion occurs, or is threatened, much mucus, leukocytes and blood are noted on the vaginal smear as well as changes in the type of vaginal epithelial cells, with some from the superficial layer and others from the intermediate or basal layers, while the typical navicular cells tend to disappear. Occasionally, fragments of placental tissue are found. Cells with pigmented granules and blood pigment are also seen, as well as histiocytes containing pigment.

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## Chapter 59

### PROGESTERONE

**SOURCES.** Progesterone is a steroid hormone, secreted by the corpus luteum of the ovary, which produces the secretory or progestational changes in the endometrium necessary for the reception and nourishment of the embryo. Corner and Allen in 1928 prepared extracts of corpora lutea having progestational activity, and the hormone itself was isolated from this source in 1934 by several independent workers. Marrian isolated the excretion product of progesterone, pregnandiol, from human pregnancy urine as early as 1929. Although progesterone was originally thought to be specific to the corpus luteum, there is now considerable evidence that progesterone can be found in the adrenal cortex, at least in some species and under certain circumstances. In fact, progesterone was isolated from ox adrenal extracts, and pregnandiol or pregnandiol-like substances have been recovered in the urine of men, ovariectomized women, and in larger amounts from patients with adrenal cortical tumors or hyperplasia.<sup>10</sup>

There is strong reason to believe that progesterone is made by the placenta in increasingly large amounts as pregnancy progresses. Although progesterone has not been isolated in pure form from this source, placental extracts with high progestational activity have been prepared. Pregnanadiol has also been recovered from the urine of a woman ovariectomized during pregnancy; moreover, pregnandiol values increase progressively during pregnancy even after the disappearance of the corpus luteum.

A number of synthetic substances with luteoid activity have been prepared. Of these the only one with sufficient activity to be of clinical significance is pregneninolone (anhydro-hydroxy-progesterone). This substance has progestational activity when given by mouth.

### BIOCHEMISTRY OF PROGESTERONE

Progesterone is a crystalline steroid having the formula  $C_{21}H_{30}O_2$ . It contains the phenanthrene cyclopentane nucleus and is chemically closely related to the estrogens and particularly to the androgens. It exists in two different crystalline forms, one melting at 128° C. (*alpha* progesterone) and the other at 121° C. (*beta* progesterone).

**PREGNANDIOL.** After its metabolism, progesterone is excreted chiefly as a water-soluble substance, sodium pregnandiol glycuronidate. This substance can be readily extracted from urine and recovered as white crystals with a melting point of 274° C.

### BIOLOGIC ACTIONS

The most significant biologic effect of progesterone is the conversion of the proliferative endometrium to a secreting phase. Under the influence of pro-

gesterone the straight tubular glands become tortuous and convoluted, lining cells become tall and columnar and secrete glycogen and other material into the lumen. This reaction apparently will not occur unless the endometrium has first been primed with estrogen. The estrogen produced along with progesterone by the corpus luteum synergizes the effect of the latter on the endometrium. The withdrawal of progesterone appears to be a factor in bringing about menstrual bleeding. Under physiologic conditions progesterone also tends to inhibit uterine contractions, particularly during pregnancy. During the progesterone phase further growth of follicles and ovulation are inhibited by progesterone hormone. Progesterone is responsible also for the proliferation of the alveolar system of the breast. On the vaginal epithelium progesterone tends to cause regression of the cornification produced by estrogens. In large doses progesterone exhibits mild androgenic effects. Retention of salt and water in the body is also influenced by progesterone. A number of other less important physiological responses have also been attributed to progesterone.

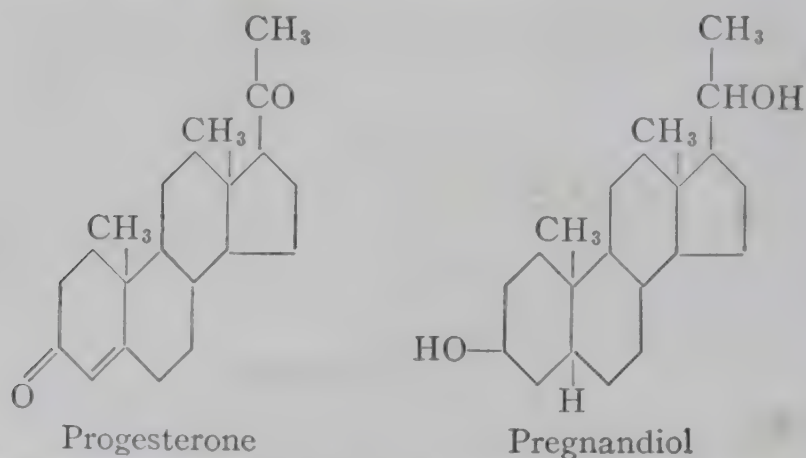


Fig. 201. Structural formulas of progesterone and pregnandiol. (Cantarow and Trumbull, *Clinical Biochemistry*.)

### NORMAL PHYSIOLOGY OF PROGESTERONE

Luteinization of the follicle cells occurs under the influence of the luteinizing hormone (L.H.) gonadotrophic factor. It is postulated that the secretion of progesterone (and estrogen) by these cells may require the synergistic action of the lactogenic hormone or some other "luteotrophic" factor. Although it is commonly stated that progesterone secretion begins sharply after ovulation, there is some evidence to indicate that even several days before ovulation some progesterone may be secreted. During the corpus luteum phase progesterone is produced in amounts estimated to be about 10 mg. per day. The largest amounts are probably produced about the twenty-first day, when the corpus luteum is most functionally active, and then drop off rapidly in the immediate premenstrual phase.

Experimental studies indicate that progesterone is rapidly inactivated in the body, but the site of inactivation is not definitely known. Zondek is of the opinion, from his *in vitro* studies, that the liver is not concerned with the inactivation of progesterone, although the chemical similarity of progesterone

the estrogens would lead one to suspect the liver as the primary site of metabolism.

It was formerly believed that a functional uterus was essential for the conversion of progesterone to pregnandiol, but it has since been shown that oophorectomized and hysterectomized women are capable of bringing about this conversion. The studies of Venning and Browne<sup>13</sup> indicate that the uterus may normally play a major role in the conversion of administered progesterone to pregnandiol, but the presence of a normal endometrium is not essential. In men the adrenal cortex has been suggested as the site of conversion of progesterone to pregnandiol.

After the metabolism of progesterone in the body the hormone is excreted in the urine, chiefly as the biologically inactive reduction product, pregnandiol. Although other reduction products of progesterone have been isolated from human urine, there is some question whether they represent excretion products of progesterone, since only pregnandiol has actually been isolated in excessive quantity after the administration of progesterone.<sup>7</sup> Moreover, pregnandiol itself has been recovered after the administration of desoxycorticosterone.<sup>4</sup> The reduction products of progesterone which have been isolated from human urine are as follows:

I. Nonketonic: Alcoholic

A. Digitonin-nonprecipitable

1. Pregnandiol-3 ( $\alpha$ )20( $\alpha$ ) (pregnandiol)
2. Allopregnandiol-3( $\alpha$ ), 20-( $\alpha$ ) (allo-pregnandiol)
3. Pregnanol-3( $\alpha$ )

B. Digiton-precipitable

1. Allopregnandiol-3( $\beta$ ), 20-( $\alpha$ )

II. Ketonic- Alcoholic

A. Digitonin-nonprecipitable

1. Pregnanol-3( $\alpha$ )-one-20 (epipregnanolone)
2. Allopregnanol-3( $\alpha$ )-one-20 (epiallopregnanolone)

B. Digitonin-precipitable

1. Allopregnanol-3( $\beta$ )-one-20

## ASSAY OF PROGESTERONE

Progesterone or extracts with progestin activity may be assayed by the Corner-Allen<sup>3</sup> method, in which a progestational effect is produced in the endometrium of rabbits castrated after coitus. Since neither progesterone nor any biologically active derivatives are excreted, urine extracts cannot be tested by this method. Moreover, the amount of progesterone present in the blood, even in pregnancy, is so low in concentration that it cannot be readily assayed by this method. A more sensitive method has been described<sup>6</sup> in which the material to be assayed is introduced directly into the rabbit uterus and an endometrial response is obtained with relatively minute amounts of progesterone.

Progesterone function is most commonly assayed by the quantitative chemical determination of pregnandiol excretion in the urine. This is usually done by gravimetric methods such as those described by Venning and Browne<sup>13</sup> or by Woodward and Jones<sup>4</sup> in which sodium pregnandiol glycuronidate is extracted

from the unhydrolyzed urine, precipitated with acetone, purified and weighed. A colorimetric method for pregnandiol determination has also been described.

The examination of endometrium taken in the premenstrual phase by biopsy or by full curettage is one of the most commonly used clinical methods for determining the presence of a corpus luteum. The histologic findings afford a highly specific method for determining progestational function. Sections prepared by Best's carmine method for glycogen afford additional specificity. Those experienced in the interpretation of endometrial sections can often estimate the degree of corpus luteum function with considerable accuracy (see Fig. 203).

**NORMAL VALUES FOR PREGNANDIOL.** Since pregnandiol normally appears in the urine in significant amounts only in association with an active corpus luteum or during pregnancy, none is found in the urine of normal children or men, at least by ordinary methods.

In women with normal ovulatory cycles pregnandiol usually appears in the urine immediately after ovulation, as indicated by various other criteria. The excretion usually begins at a rather low level of about 2 to 5 mg. per twenty-four hours, but within several days usually increases to 5 to 10 mg. per twenty-four hours, occasionally going as high as 12 mg. The day-to-day excretion during the luteal phase is often irregular, and on occasion may apparently disappear for twenty-four hours, although spontaneous hydrolysis of the urine or errors in technic must be considered as possibilities in the latter event. Pregnanndiol values frequently drop to less than 5 mg. several days before the flow and often disappear entirely for the twenty-four to forty-eight hours preceding menstruation. On occasion some pregnandiol is present into the first day of bleeding. The curve of pregnandiol excretion tends to parallel the development, activity and regression of the corpus luteum. The total excretion for a cycle generally ranges from about 40 to 50 mg., but variations from 20 to 80 mg. are encountered.

Occasional workers have reported the presence of pregnandiol in the urine in the absence of ovulation or a functioning corpus luteum, as indicated by absence of a progestational endometrium, but this has not been supported by the findings of most observers. Commonly, however, a progestational endometrium has been found at the end of a cycle in which no pregnandiol was excreted. These observations raise the problems as to whether an unruptured follicle may undergo luteinization and produce pregnandiol, whether pregnandiol is excreted in appreciable amounts by sources other than the ovary, whether some secretory effects may be produced in the endometrium in the absence of progesterone, and so forth.

**PREGNANCY.** In the menstrual cycle in which conception occurs the pregnandiol excretion does not diminish, but is maintained at levels of about 4 to 10 mg. (Table 290), owing to the persistence of the corpus luteum. During the first six weeks of gestation (eight weeks of amenorrhea) the pregnandiol levels do not increase appreciably. The average values increase slowly during the second eight weeks of amenorrhea, although in some instances the values may still be within the nonpregnancy range. During these early weeks it is presumed that most of the pregnandiol is derived from progesterone secreted by the corpus luteum, but that the placenta takes over this function as the

corpus luteum of pregnancy regresses. The pregnandiol values now increase more rapidly and progressively to reach values of about 50 to 120 mg. near term (Fig. 202, Table 290).

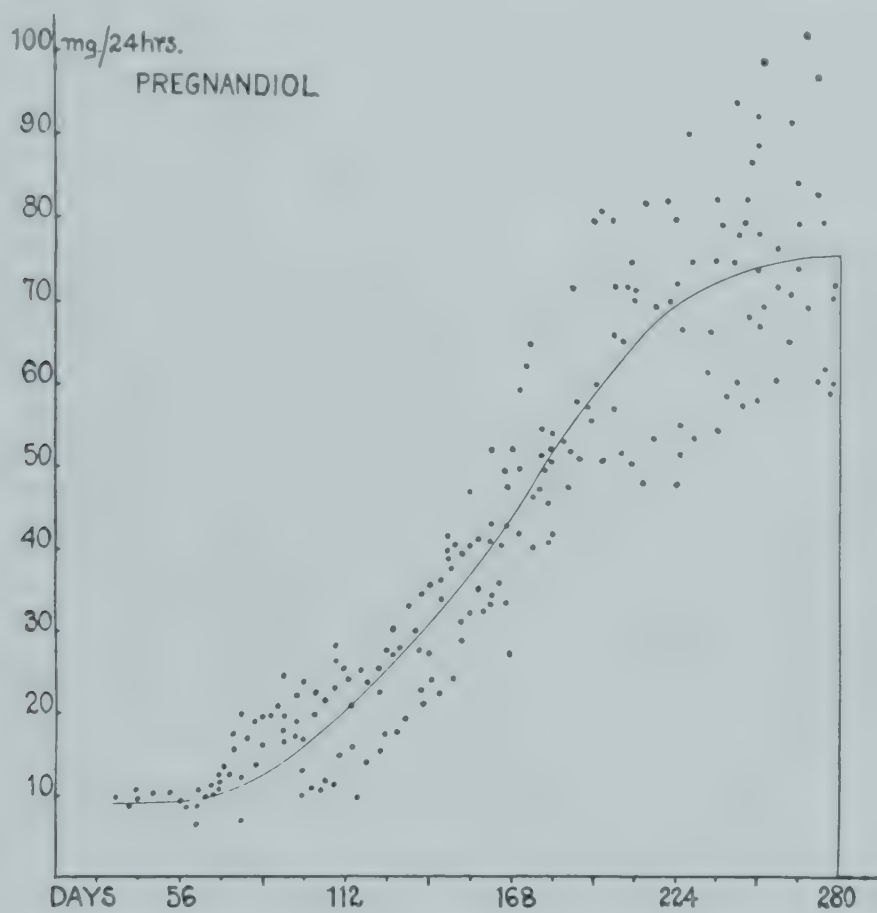


Fig. 202. Urinary excretion of pregnandiol in normal pregnancy (eight cases). (Venning, E. H.: J. Biol. Chem., vol. 126.)

TABLE 290  
PREGNANDIOL VALUES IN PREGNANCY

Weeks of Amenorrhea	Pregnandiol (Urine) Mg./24 Hours	
	Range	Average
2.....	2- 10	6
4.....	5- 15	10
8.....	5- 15	10
12.....	8- 20	12
16.....	8- 30	20
20.....	16- 32	25
24.....	20- 60	40
28.....	35- 80	50
32.....	40- 80	60
36.....	50-100	68
40.....	50-120	70

Several observers have noted a fall in pregnandiol beginning one to two weeks before the onset of labor. These findings, however, do not appear to occur consistently in all patients.

Immediately after delivery there is a precipitous drop in pregnandiol excretion so that within two or three days no pregnandiol can be recovered.

The finding of pregnandiol in the urine has been suggested as a test of pregnancy on the basis that pregnandiol does not occur in the urine of women with amenorrhea, except in pregnancy. Guterman<sup>2</sup> has suggested a color test for pregnandiol based on the development of an orange color when extracts are treated with sulfuric acid. There is some question whether the reaction is sufficiently specific to yield accurate results in all cases.

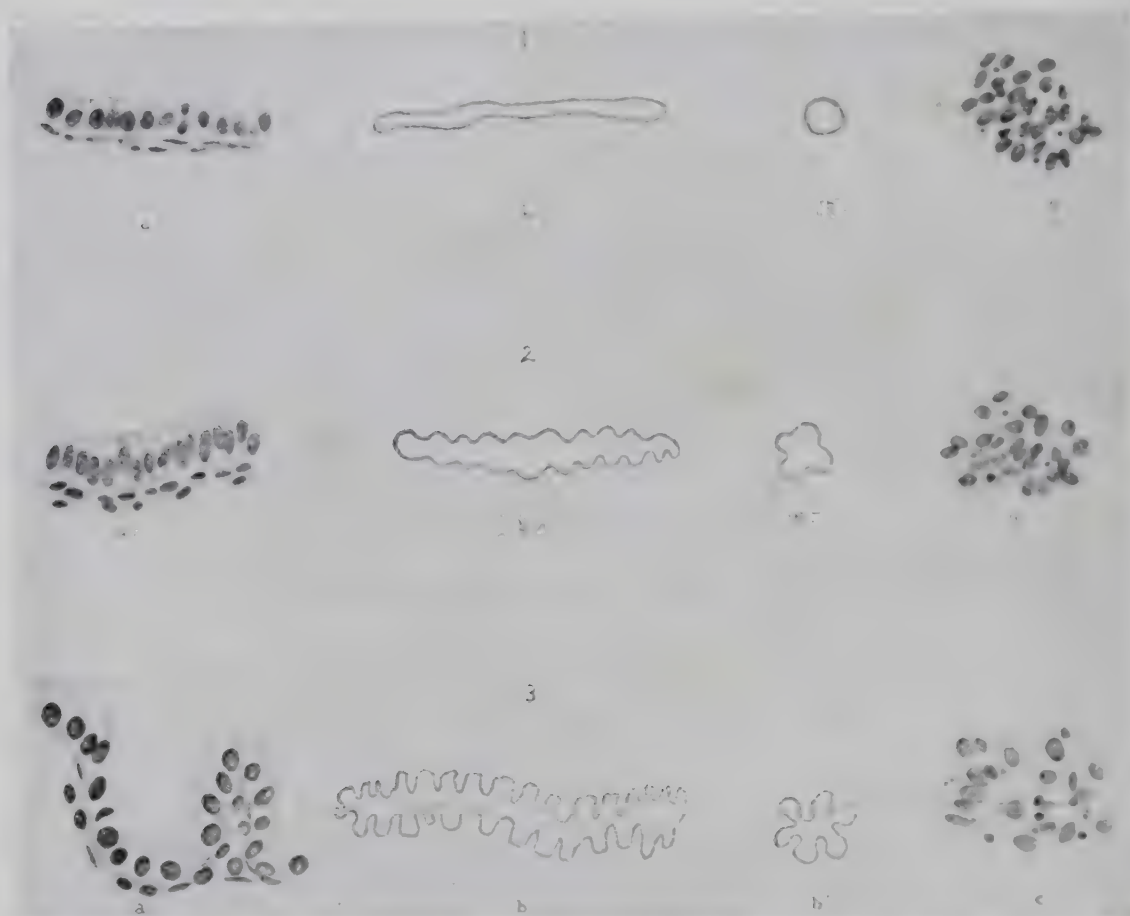


Fig. 203. Characteristic changes in the uterine epithelium, glands and stroma at the various stages of the menstrual cycle. 1, Postmenstrual; 2, interval; 3, premenstrual: a, epithelium; b, glands; c, stroma. Note the secretory changes indicative of progesterone activity, as shown in 3. (Novak, E.: *Gynecology and Female Endocrinology*, Williams & Wilkins Co.)

Progesterone or substances with progestational activity have not been found in the urine.

Haskins,<sup>6</sup> using the sensitive intra-uterine technic elaborated by McGinty and his co-workers,<sup>7</sup> has demonstrated a progestationally active substance in the serum of pregnant women. No quantitative estimations are available.

**ENDOMETRIUM.** Careful histologic examination of the endometrium affords qualitative and some degree of quantitative evidence of progesterone function (Fig. 203).

Two or three days after ovulation the first changes in the endometrial cells indicative of a secretory or a corpus luteum effect are noted. A clear area

develops in the deeper part of the cell body and the nucleus moves up toward the lumen. With differential staining, secretory granules may be detectable in the cytoplasm, though not yet in the lumina. The glands become more hypertrophic and more convoluted, and the lumina increasingly larger. These changes are much less marked in the neck of the glands than in the middle zone, giving rise, therefore, to two functional layers, a compact layer on the surface (decidua compacta) and a spongy layer below (decidua spongiosa). In the basal layer (basalis) the gland epithelium is of more immature type and is less sensitive to progesterone.

As the cycle advances, the glands become markedly tortuous and twisted. On longitudinal section they show a characteristic dentate or saw-tooth outline. The lining cells become paler and lower and the edges become frayed. Best's carmine and mucicarmine stains show abundant glycogen and mucus in the cells and in the lumina, the stromal cells become larger, and the amount of cytoplasm increases. There is also increased vascularity.

In the immediate premenstrual stage there is marked leukocytic infiltration in the upper layers. The lining cells show degenerative changes, progressive loss of secretion and pyknosis of nuclei. There is disappearance of edema and shrinkage in the thickness of the endometrium. The stromal cells at this stage often resemble decidual cells.

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## Chapter 60

### GONADOTROPHIC HORMONES

THE ANTERIOR lobe of the pituitary gland secretes at least two gonadotrophic substances by which ovarian and testicular functions are regulated.

FOLLICLE-STIMULATING HORMONE (F.S.H.) OR GAMETOKINETIC GONADOTROPHIN (PROLAN A). In women this hormone stimulates growth of the ovarian follicles and in the presence of small amounts of the second gonadotrophic hormone (luteinizing hormone) causes the secretion of estrogen by the ovary. In men this hormone is responsible for the growth of the tubules of the testes and for spermatogenesis.

LUTEINIZING HORMONE (L.H.) OR INTERSTITIAL-CELL-STIMULATING HORMONE (ICSH) (PROLAN B). This hormone is responsible for the development of the corpus luteum in the ovary and the secretion of progesterone as well as additional estrogen. Some evidence suggests that the secretory function of the corpus luteum is caused by a third or "luteotrophic" gonadotrophin. This is believed to be identical with prolactin (lactogenic hormone). In men the luteinizing hormone stimulates the development of the interstitial cells of Leydig in the testes and the production of male sex hormone.

During pregnancy another distinct gonadotrophic hormone is produced by the chorionic cells of the placenta and is termed *chorionic gonadotrophin*, also sometimes referred to as "A.P.L." since in many of its actions it is similar to the luteinizing hormone factor of the pituitary and is, therefore, an interstitial-cell-stimulating hormone.

The gonadotrophic hormones are complex glycoproteins of molecular weight of about 60,000 to 80,000, the exact chemical structure of which is not known. These substances cannot be isolated from biologic fluids in a state of purity, nor can their presence be detected by any known chemical method. Relatively small amounts, however, can be demonstrated by biologic assay based upon any of several specific effects on test animals. The method to be used depends upon which gonadotrophic substance is present and whether a qualitative or quantitative result is sought.

### ASSAY OF GONADOTROPHINS

The biologic assays used for determining pituitary gonadotrophins in the urine or blood of nonpregnant women are procedures which are most sensitive to the follicle-stimulating hormone fraction and are, indeed, often called "tests for follicle-stimulating hormone"; however, they really determine combined follicle-stimulating and luteinizing hormones.

URINE. The gonadotrophin content of the urine is normally so low that concentration of the hormone in a twelve or twenty-four-hour specimen is generally required. Usually this is accomplished by precipitating the hormone along

with other proteins from the acidified urine with ethyl alcohol or tannic acid, washing and drying the precipitate with alcohol and ether or acetone, and extracting the gonadotrophins with water or aqueous buffer solutions. Dialysis of the extract to remove toxic substances may be necessary if large amounts of urine extract are to be injected. The hormone fraction can also be obtained by ultrafiltration of urine.<sup>4</sup>

Heller and Heller,<sup>5</sup> Levin and Tyndale<sup>7</sup> and Klinefelter and his co-workers,<sup>6</sup> have described suitable extraction technics, and bio-assay of the extracts may be obtained by methods which test the response on the ovaries, uteri or seminal vesicles of infantile rats or mice. It is generally accepted that the measurement of the increase in uterine weight of the infantile mouse is probably the most sensitive and satisfactory method for this purpose.

**SERUM.** The concentration of gonadotrophic substances in the blood or serum is not appreciably higher than in the urine, so that measurement of the hormone in the serum of normal nonpregnant subjects is usually not feasible. At the midcycle, when the hormone concentration is highest, and in the serum of menopausal women it is possible to demonstrate the presence of gonadotrophins by histologic examination of the ovaries of infantile mice that have been injected with serum.<sup>3</sup>

#### TESTS FOR CHORIONIC GONADOTROPHIN

Chorionic gonadotrophic hormone is usually demonstrated by the Aschheim-Zondek reaction, namely, the production of corpora hemorrhagica or corpora lutea on the ovaries of infantile rats or mice. The least amount of material which will produce this reaction (macroscopic), in half of the animals is generally considered to contain 1 mouse or rat ovarian unit. One international unit of chorionic gonadotrophin is equivalent to biologic activity contained in 0.1 mg. of the international standard provided by the League of Nations.

#### TESTS FOR PREGNANCY

During normal pregnancy chorionic gonadotrophin is present in such high concentration that it can readily be demonstrated in small amounts of urine or blood and can thus be used as a test for pregnancy, since so high a titer is not ordinarily encountered in any other condition.

**ASCHHEIM-ZONDEK (A-Z) TEST.** This involves the production of corpora hemorrhagica or corpora lutea on the ovaries of infantile mice or rats ninety-six hours after the first of a series of injections of urine or serum.

**FRIEDMAN TEST.** A positive test is the production of fresh blood-points (corpora hemorrhagica) on the ovaries of a young adult rabbit forty-eight hours after intravenous injection of whole urine or serum.

**FROG TESTS.** (a) *South African Frog (Xenopus laevis)*.<sup>8</sup> This test depends on finding extruded eggs within twelve hours of injection of pregnancy urine into the dorsal lymph sac of the female, (b) *North American Frog (Rana pipiens)*.<sup>9</sup> This test depends upon the release of spermatozoa by the male frog within two hours of injection of pregnancy urine.

**TWO-HOUR OR SIX-HOUR RAT TEST.** This rapid test depends on the production of hyperemia or reddening of the ovaries of infantile rats within two to six hours after the intraperitoneal injection of serum or urine.

**INTERPRETATION OF PREGNANCY TESTS.** The biologic tests for pregnancy which are generally used are based upon the demonstration of high titers of gonadotrophin and are not qualitatively specific for any substance found only in pregnancy. It is, therefore, apparent that the test will be influenced considerably by the sensitivity of the method for demonstrating gonadotrophin as well as the amount of gonadotrophic hormone being excreted by the patient.

#### FRIEDMAN RABBIT TEST

**Basis:** Marked increase in gonadotropic hormone content of the urine after conception.

**Test Animal:** Sexually mature unmated female rabbit not less than 4 months old and isolated for one month before test is performed.

**Biologic Criteria:** Ovulation and formation of corpora lutea in ovary.

**Procedure:** (1) Inject into the marginal vein of the ear 10 cc. of morning urine. (2) Give second injection of 10 cc. ten to fifteen hours later. (3) Autopsy at end of 48 hours after first injection and remove ovaries for inspection.

**Reaction:** Positive when subserous hemorrhagic areas or corpora lutea are present in ovaries. Negative if clear retention follicles without hemorrhagic areas are seen.



POSITIVE



NEGATIVE

#### ASCHHEIM-ZONDEK TEST

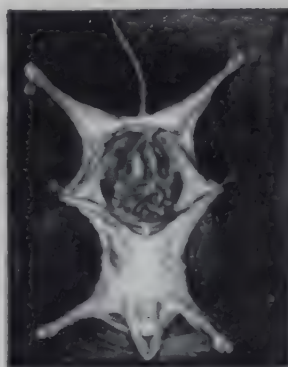
**Basis:** Marked increase in gonadotropic hormone content of the urine after conception.

**Test Animal:** Infantile white mouse weighing 6-8 gms. or 17-21 days old.

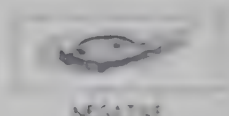
**Biologic Criteria:** Production of hemorrhagic follicles or corpora lutea in ovary.

**Procedure:** (1) Inject each of 5 animals subcutaneously with 2.4 cc. morning urine in 6 divided doses in the course of 3 days. (2) Autopsy on fifth day after the first injection and examine ovaries, macroscopically with a hand lens or if in doubt microscopically.

**Reaction:** Positive when the ovaries show hemorrhagic follicles or corpora lutea.



POSITIVE



NEGATIVE

Fig. 204. Biologic tests for pregnancy. (Hoffman: Female Endocrinology.)

**FALSE-POSITIVE REACTIONS.** False-positive pregnancy tests may be observed in patients excreting large amounts of gonadotrophic hormone.

Menopausal women or even younger women with a primary ovarian deficiency may, on occasion, excrete sufficient hormone to give a false-positive pregnancy test. (It is estimated that 5 per cent of all menopausal patients may on occasion have a "positive pregnancy test.")

Occasionally patients suffering from basophilic or eosinophilic tumors of the pituitary gland may excrete sufficient hormone during the early stages of the lesion to give false-positive reactions. Later, diminished titers are excreted.

Large amounts of chorionic gonadotrophic hormones may be excreted in the urine of patients suffering from chorionic tumors such as hydatidiform mole, chorionepithelioma and certain embryonal tumors of the testes. Likewise, when placental tissue has been retained after a normal delivery or abortion, the test may be positive for many days or even weeks, so long as viable placental tissue remains.

False-positive reactions may occur as the result of technical difficulties such as using improperly isolated rabbits for the Friedman test or over-aged mice for the Aschheim-Zondek test.

**FALSE-NEGATIVE REACTIONS.** If the test for pregnancy is undertaken too early in gestation, sufficient hormone may not be present to give a positive reaction. As a rule, the pregnancy tests are not fully reliable until ten days after the first missed period, although many patients may give a positive reaction a few days earlier, and on rare occasions a patient may have a positive test even before the first period has been missed. If there has been delay in ovulation and placentation, the positive test may be delayed twelve or fourteen days after the first missed period.

After intra-uterine fetal death the Friedman test usually becomes negative; however, it may continue to be positive for some week afterward.

In about 75 per cent of ectopic pregnancies, pregnancy tests are positive. They are often negative in patients with threatened abortion or in whom the chorionic villi have become detached.

False-negative tests may also result from errors in technic or refractoriness of the test animal. The latter difficulty occurs most often with the South African frog test, but is not uncommon with the rat ovary hyperemia test.

### NORMAL GONADOTROPHIN VALUES

**CHILDHOOD.** Probably some degree of pituitary gonadotrophic function is present throughout childhood and is responsible for the minimal growth and development of the gonads. The quantity of hormone excreted in the urine of young children is too small, however, to be detected by ordinary methods.

As the child begins to approach puberty, small amounts of gonadotrophins can be extracted from the urine. In girls, after the menarche is reached, it is not unusual to find sudden spurts of gonadotrophic excretion. In some pubertal girls amounts of gonadotrophins from 30 to 200 mouse units may be excreted in the urine over a period of twenty-four hours. This increased activity may possibly be interpreted as an attempt on the part of the pituitary to establish normal ovarian cycling. The day-to-day gonadotrophic excretion during the pubertal period is often irregular until a normal ovulatory cycle is established and often is associated with menstrual irregularity and "functional" or so-called "pubertal" bleeding.

In boys, gonadotrophic hormone cannot be demonstrated in the urine before the age of twelve or thirteen years, or even later when sexual maturation is delayed. In early puberty, 6 to 12 mouse units may be contained in twenty-four-hour collections of urine; only rarely are higher values noted in maturing boys.

**FEMALE REPRODUCTIVE PERIOD.** Throughout the years of normal menstrual function, production of gonadotrophic hormone continues in cyclic fashion so that variable amounts are present in the urine and blood. During the first half of the follicular phase the hormone is chiefly of the follicle-stimulating type; after ovulation it is mostly luteinizing hormone. By ordinary methods of assay it is not possible to determine the proportion of each, but rather the combined effect of both. The mouse uterine weight method is most sensitive for the follicle-stimulating hormone.

TABLE 291  
URINE GONADOTROPHIN VALUES  
(Rakoff, 1942)<sup>8</sup>

<i>Gonadotrophins in Mouse Uterine Weight Units</i>	<i>Female, Days of Menstrual Cycle</i>				<i>Menopausal Women</i>	<i>Male</i>
	7	14	21	28		
Range.....	Traces-12	8-40*	Traces-8	0-6	32-300	4-24
Average.....	6	20	6	Traces	80	8

\* Higher values may occasionally occur at the midcycle peak.

Some gonadotrophic hormone is excreted in the urine at all phases of the menstrual cycle with a rather marked increase for a brief period at the midcycle. Table 291 summarizes the values usually found by Rakoff at various phases of the menstrual cycle. The increase encountered about the time of the midcycle is usually sudden and sharp. In some patients more than one such peak and as many as three sometimes occur (Fig. 205). The peak in excretion is usually believed to occur several days before ovulation. Sometimes marked increase in hormone may be sufficient to be detected in the unconcentrated urine by using a sensitive end point, such as the production of hyperemia in the ovaries of infantile rats. Farris (1946) suggested this as a test for ovulation on the basis that a positive hyperemia test is obtained on each of the three days preceding ovulation. Additional single daily peaks may be obtained at sporadic intervals as shown by quantitative assay or the hyperemia test; their significance is not known.

After the peak at ovulation the gonadotrophic content in the urine decreases rapidly to values of 6 to 12 mouse units per twenty-four hours. Immediately before menstruation often only traces of gonadotrophic hormone are present.

In the serum the amount of hormone is usually too small to be readily detected at any phase of the cycle.

**MENOPAUSAL AND POSTMENOPAUSAL PERIOD.** As the menopausal years are approached, detectable concentrations of gonadotrophic hormone are found in the serum and larger amounts are excreted in the urine. In the premenopausal phase the increased titer of gonadotrophic hormone is the first indication of failing ovarian function, since apparently more and more pituitary stimulation

s required to induce ovarian activity. Finally, the time is reached when adequate estrogen production fails despite a persistently high level of gonadotrophic stimulation and the cyclic rise and fall of the excretion level appears to be lost. The hormone excreted during this period is almost entirely of the follicle-stimulating type (Fig. 206), although many workers believe that the gonadotrophic hormone in postmenopausal women differs qualitatively from the follicle-stimulating hormone of normal women. It is quite usual for menopausal women to excrete more than 100 mouse units of gonadotrophic hormone daily; many, indeed, will excrete 300 or more mouse units per twenty-four hours.

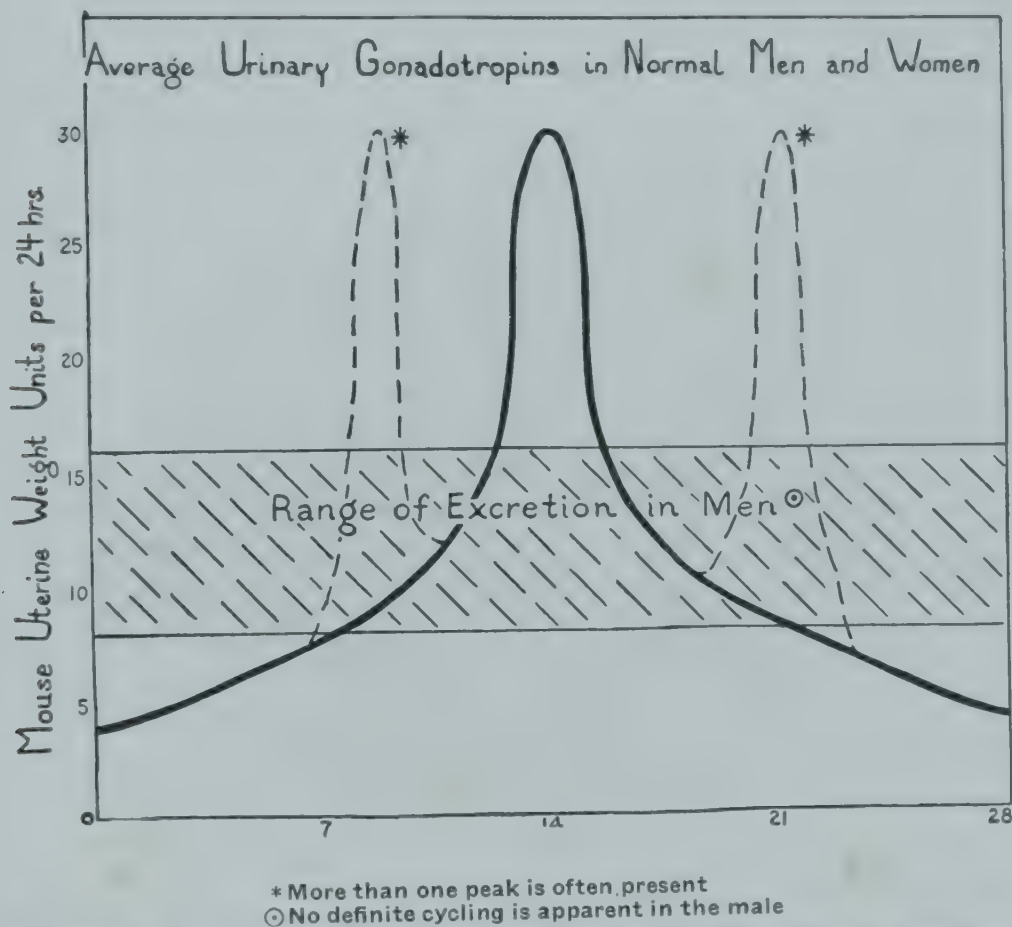


Fig. 205. Days of the menstrual cycle. (Rakoff, A. E.: M. Clin. North America, vol. 26.)

The excretion of high titers of gonadotrophic hormone usually continues for many years after the menopause and often into old age, even in women castrated in their youth.

**PREGNANCY.** During pregnancy relatively high amounts of a luteinizing type of gonadotrophic substance are present in the blood and urine. Since there is strong reason to believe that this hormone is secreted by the chorionic cells of the placenta this is termed *chorionic gonadotrophic hormone*. It is probable that the pituitary does not secrete gonadotrophins in any appreciable quantity during pregnancy. Although, superficially, chorionic gonadotrophin resembles the luteinizing hormone of the anterior pituitary in its action, it differs in one important respect in that it fails to evoke follicular growth or maturation in the hypophysectomized immature rat. In the absence of the pituitary the chief effect

is stimulation and luteinization of the interstitial and thecal cells and secretion of estrogens and progesterone.

Chorionic gonadotrophin begins to appear in the blood and urine soon after implantation, which generally occurs in the last week of the cycle in which conception took place. The hormonal titer rises progressively, and by ten days after the first missed menses the tests for pregnancy are uniformly positive.

**BLOOD VALUES.** The concentration of gonadotrophins in the blood serum becomes enormously increased about the sixth to eighth week of gestation (eighth to tenth week of amenorrhea), at which time values of 33,000 mouse units per 100 ml. of serum may be observed. Although in many patients the titer begins to fall rapidly soon after the peak, moderately high values are

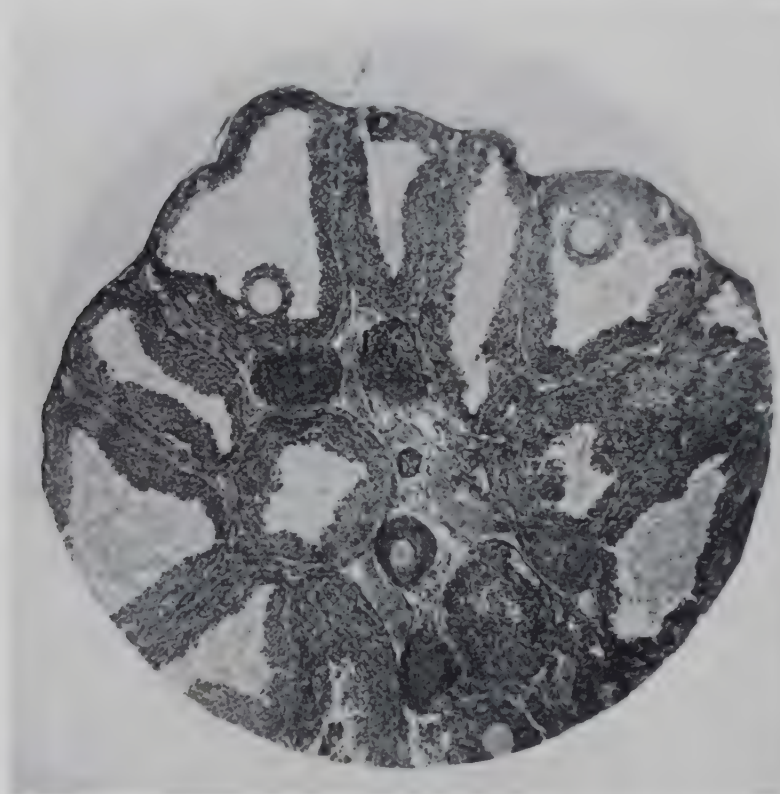


Fig. 206. Induction of follicle growth in the ovary of an immature mouse injected with urine extract of a menopausal woman. (Fluhmann: Menstrual Disorders.)

observed up to the sixteenth week of amenorrhea. By the twentieth week of amenorrhea marked falling occurs in most cases. Throughout the latter half of pregnancy the titer concentration of gonadotrophins is usually from 300 to 500 mouse units per 100 ml. After delivery the serum gonadotrophins rapidly fall and within ninety-six hours of delivery are usually nondemonstrable. If any placental tissue has been retained, moderate amounts of hormone, often enough to give a positive pregnancy test, may be present for a week or even longer.

**URINE VALUES.** In the human the urinary excretion of chorionic gonadotrophins during pregnancy may be correlated with the concentration in serum.

According to Browne and his co-workers,<sup>1</sup> the concentration of gonadotrophins in the urine gradually increases until at the thirty-second day it may vary from 200 to 500 rat units per liter (for chorionic gonadotrophin the mouse

unit and rat unit are approximately equal). Subsequently the concentration increases rapidly, reaching a peak between the fifty-second and sixty-fourth days of from 133,000 to 400,000 rat units (occasionally over a million rat units may be excreted in twenty-four hours). About the sixty-seventh day a sharp

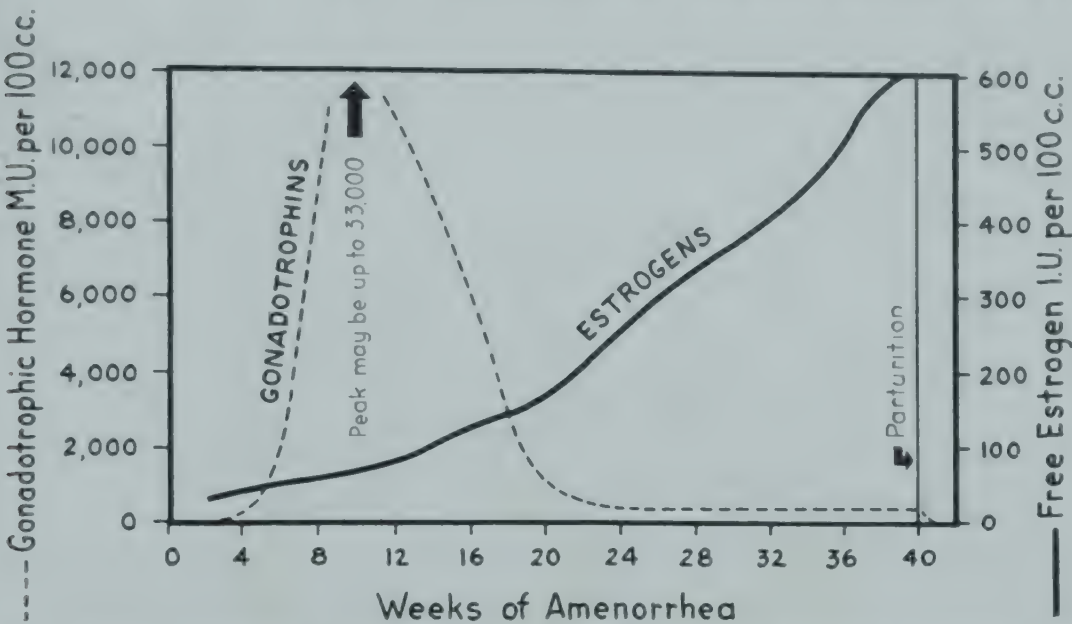


Fig. 207. Gonadotrophin and estrogen values in the blood during normal pregnancy. (Cantarow and Trumper: Clinical Biochemistry.)

decline to 40,000 or less rat units per liter may be observed; after the 126th day values may be decreased from 1500 to 5000 rat units. During the last trimester of pregnancy an increase in gonadotrophins may be noted in some patients. A similar rise is often noted in toxemic or diabetic women.

TABLE 292  
SERUM GONADOTROPHIN VALUES IN PREGNANCY  
(From Cantarow and Trumper, 1945)<sup>2</sup>

Weeks of Amenorrhea	Serum Gonadotrophins M.U./100 Ml.	
	Range	Average
4.....	50- 1000	200
8.....	500-33000	10000
12.....	1000-33000	10000
16.....	1000-33000	6000
20.....	330-10000	1000
24.....	200- 500	330
28.....	200- 500	330
32.....	200- 500	330
36.....	200- 500	330
40.....	200- 500	330

MALE. The sexually mature male regularly excretes moderate amounts of gonadotrophic hormone. The type of hormone is chiefly the follicle-stimulating variety and apparently is similar to the gonadotrophin excreted by postmenopausal women rather than that of normally menstruating women. The average

daily excretion of gonadotrophins in men is generally higher than in women, except for the increase at the midcycle. Average daily values of 8 to 20 m.u. units per twenty-four hours are common.

TABLE 293

URINARY EXCRETION OF CHORION GONADOTROPHIN [PROLAN] IN 8 CASES OF NORMAL PREGNANCY

(Browne et al., 1939)<sup>1</sup>

<i>Days of Amenorrhea</i>	<i>Chorion Gonadotrophin R.U./24 Hours</i>
28- 56.....	700- 50000
56- 84.....	10000-200000
84-112.....	3000- 28000
112-140.....	2000- 10000
140-168.....	1000- 10000
168-196.....	1000- 15000
196-224.....	3000- 13000
224-252.....	1000- 24000
252-280.....	2000- 10000

Although some men past the age of fifty years may show a moderate increase in titers of gonadotrophins, this occurs with much less frequency than in the menopausal woman, nor are the titers likely to be as high. Such increases have been noted in some men suspected of the “male climacteric” syndrome. Since this condition is not often associated with the clear-cut clinical manifestations of the menopausal syndrome in women, the estimation of gonadotrophins may be of value in differential diagnosis.

Male castrates regularly excrete increased amounts of gonadotrophic hormone over a period of many years, even if orchidectomy was carried out before puberty.

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Section XVI  
METABOLISM AND NUTRITION  
(Normal Values)



## Chapter 61

### BODY METABOLISM

#### BASAL METABOLISM

**CALCULATION OF SURFACE AREA.** Basal metabolism is the measurement of heat production in the morning twelve to fourteen hours after the last meal, with the subject lying quietly for at least a half hour.

The metabolism of warm-blooded animals is proportional to the surface area; therefore it is customary to express metabolism in terms of calories per square meter of body surface.

The DuBois and DuBois<sup>6</sup> formula for determining surface area is usually employed in this country. It may be expressed as follows:

$$A = H^{0.725} \times W^{0.425} \times C$$

where  $A$  is area,  $W$  is weight,  $H$  is height,  $C$  is constant 71.84; or

$$\text{Log } A = \text{Log } H \times 0.725 + \text{Log } W \times 0.425 + 1.8564$$

The surface area based on this equation for any height and weight can easily be found by using the nomogram of DuBois and DuBois (Fig. 208) or that of Boothby and Sandiford.<sup>4a</sup> Stoner calculated surface areas over an extensive range of heights and weights (Tables 294 to 299, inclusive), which may be used when more accuracy is desired than is obtained by the nomograms.



Fig. 207a. Nomogram permitting direct estimation of surface area from height and weight by Dubois' formula  $A = H^{0.725} \times W^{0.425} \times 71.84$ . When  $A$  = surface area in square centimeters,  $H$  = height in centimeters and  $W$  = weight in kilos. (sq. cm. = sq. m.  $\times$  10,000.) The surface area is found at the point of intersection of the middle scale with a straight line drawn from the observed height on the left hand scale to the observed weight on the right hand scale.

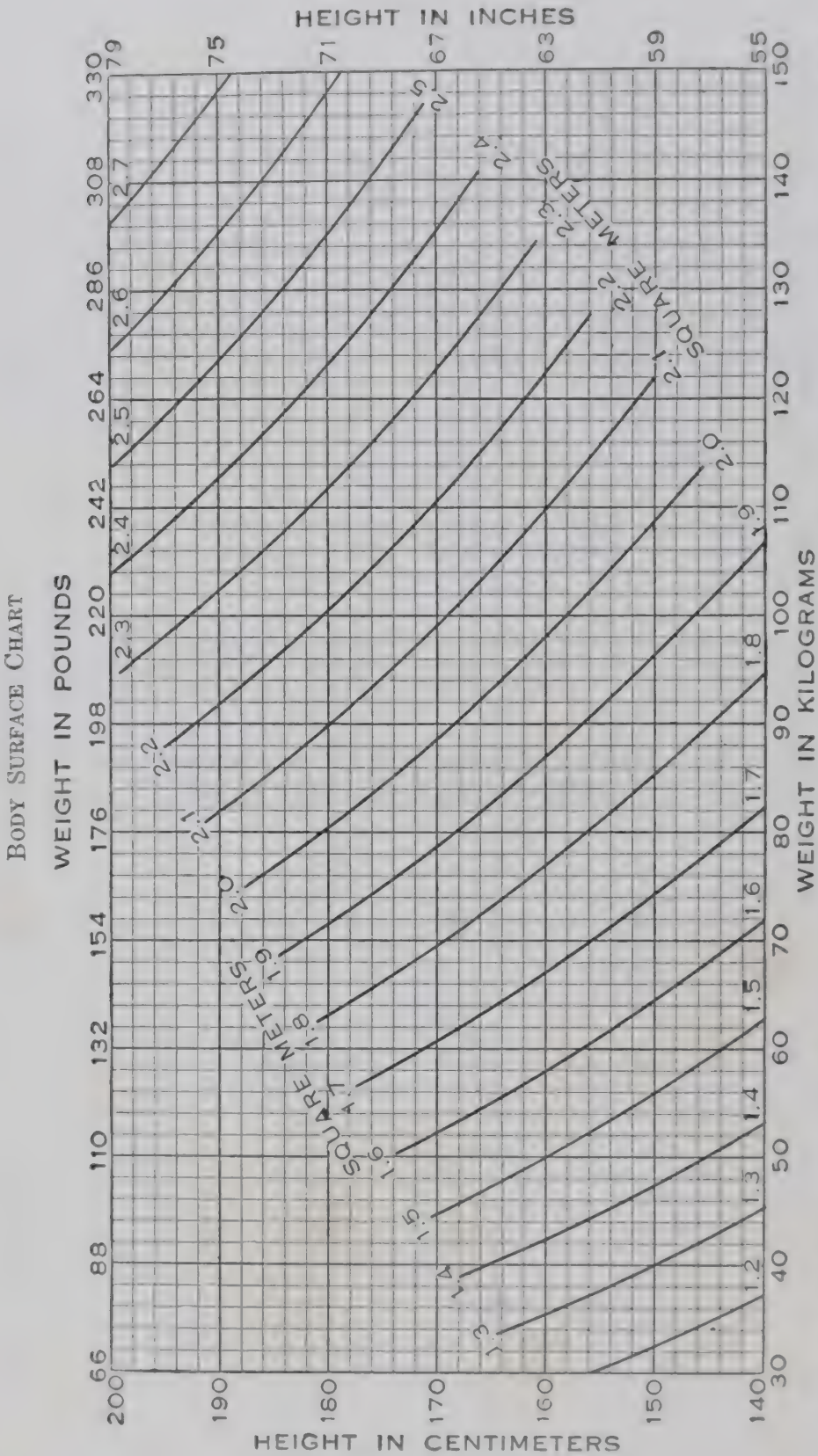


Fig. 208. DuBois' chart for determining surface area of man in square meters from weight in kilograms (Wt.) and height in centimeters (Ht.) according to the formula:  $\text{Area (sq. cm.)} = H^{0.725} \times W^{0.425} \times 71.84$ . (McLester: Nutrition and Diet in Health and Disease.)

TABLE 294

SURFACE AREA IN SQUARE METERS (DuBois Formula) . 20 KG. TO 34 KG., 110 CM. TO 174 CM.  
(Stoner, 1926)<sup>17</sup>

$\frac{K_a}{m}$	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
110.	0.775	0.791	0.807	0.823	0.838	0.852	0.867	0.881	0.894	0.908	0.921	0.934	0.947	0.959	0.971
111.	0.780	0.796	0.812	0.828	0.843	0.858	0.872	0.886	0.900	0.914	0.927	0.940	0.953	0.965	0.978
112.	0.785	0.802	0.818	0.833	0.848	0.863	0.878	0.892	0.906	0.920	0.933	0.946	0.959	0.972	0.984
113.	0.790	0.807	0.823	0.839	0.854	0.869	0.884	0.898	0.912	0.926	0.939	0.952	0.965	0.978	0.991
114.	0.795	0.812	0.828	0.844	0.860	0.875	0.889	0.904	0.918	0.932	0.945	0.959	0.972	0.984	0.997
115.	0.800	0.817	0.833	0.849	0.865	0.880	0.895	0.909	0.923	0.937	0.951	0.965	0.978	0.991	1.003
116.	0.806	0.823	0.839	0.855	0.871	0.886	0.901	0.915	0.929	0.943	0.957	0.971	0.984	0.997	1.010
117.	0.811	0.828	0.844	0.860	0.876	0.891	0.906	0.921	0.935	0.949	0.963	0.977	0.990	1.003	1.016
118.	0.816	0.833	0.849	0.865	0.881	0.897	0.912	0.927	0.941	0.955	0.969	0.983	0.996	1.009	1.022
119.	0.821	0.838	0.854	0.871	0.887	0.902	0.917	0.932	0.947	0.961	0.975	0.989	1.002	1.015	1.028
120.	0.826	0.843	0.860	0.876	0.892	0.908	0.923	0.938	0.952	0.967	0.981	0.995	1.008	1.022	1.035
121.	0.831	0.848	0.865	0.881	0.898	0.913	0.928	0.943	0.958	0.973	0.987	1.001	1.014	1.028	1.041
122.	0.836	0.853	0.870	0.887	0.903	0.919	0.934	0.949	0.964	0.978	0.993	1.007	1.020	1.034	1.047
123.	0.841	0.858	0.875	0.892	0.908	0.924	0.939	0.955	0.970	0.984	0.999	1.013	1.027	1.040	1.053
124.	0.845	0.863	0.880	0.897	0.914	0.930	0.945	0.960	0.975	0.990	1.004	1.019	1.033	1.046	1.059
125.	0.850	0.868	0.886	0.903	0.919	0.935	0.951	0.966	0.981	0.966	1.010	1.025	1.039	1.052	1.066
126.	0.855	0.873	0.891	0.908	0.924	0.940	0.956	0.972	0.987	1.002	1.016	1.031	1.045	1.059	1.072
127.	0.860	0.878	0.896	0.913	0.930	0.946	0.962	0.977	0.992	1.007	1.022	1.037	1.051	1.065	1.078
128.	0.865	0.883	0.901	0.918	0.935	0.951	0.967	0.983	0.998	1.013	1.028	1.043	1.057	1.071	1.084
129.	0.870	0.888	0.906	0.923	0.940	0.957	0.973	0.989	1.004	1.019	1.034	1.048	1.063	1.077	1.090
130.	0.875	0.893	0.911	0.928	0.945	0.962	0.978	0.994	1.009	1.024	1.039	1.054	1.069	1.083	1.096
131.	0.880	0.898	0.916	0.934	0.951	0.968	0.984	0.999	1.015	1.030	1.045	1.060	1.075	1.089	1.103
132.	0.885	0.903	0.921	0.939	0.956	0.973	0.989	1.005	1.020	1.036	1.051	1.066	1.080	1.095	1.109
133.	0.889	0.908	0.926	0.944	0.961	0.978	0.994	1.010	1.026	1.042	1.057	1.072	1.086	1.101	1.115
134.	0.894	0.913	0.931	0.949	0.966	0.983	0.999	1.016	1.032	1.047	1.062	1.077	1.092	1.107	1.121
135.	0.899	0.918	0.936	0.954	0.972	0.989	1.005	1.021	1.037	1.053	1.068	1.083	1.098	1.113	1.127
136.	0.904	0.923	0.941	0.959	0.977	0.994	1.010	1.027	1.043	1.059	1.074	1.089	1.104	1.119	1.133
137.	0.909	0.928	0.946	0.964	0.982	0.999	1.016	1.032	1.048	1.064	1.080	1.095	1.110	1.125	1.139
138.	0.914	0.933	0.951	0.969	0.987	1.004	1.021	1.037	1.054	1.070	1.085	1.101	1.116	1.131	1.145
139.	0.919	0.938	0.956	0.975	0.993	1.010	1.027	1.043	1.060	1.076	1.091	1.107	1.122	1.136	1.151
140.	0.923	0.942	0.961	0.980	0.998	1.015	1.032	1.049	1.065	1.081	1.097	1.112	1.127	1.142	1.157
141.	0.928	0.947	0.966	0.985	1.003	1.020	1.037	1.054	1.071	1.087	1.103	1.118	1.133	1.148	1.163
142.	0.933	0.952	0.971	0.990	1.008	1.026	1.043	1.060	1.076	1.092	1.108	1.124	1.139	1.154	1.169
143.	0.937	0.957	0.976	0.995	1.013	1.031	1.048	1.065	1.081	1.098	1.114	1.130	1.145	1.160	1.175
144.	0.942	0.962	0.981	1.000	1.018	1.036	1.053	1.070	1.087	1.103	1.119	1.135	1.151	1.166	1.181
145.	0.947	0.967	0.986	1.005	1.023	1.041	1.059	1.076	1.092	1.109	1.125	1.141	1.157	1.172	1.187
146.	0.951	0.971	0.991	1.010	1.029	1.047	1.064	1.081	1.098	1.115	1.131	1.147	1.163	1.178	1.193
147.	0.956	0.976	0.996	1.015	1.034	1.052	1.069	1.086	1.103	1.120	1.136	1.152	1.168	1.184	1.199
148.	0.961	0.981	1.001	1.020	1.039	1.057	1.074	1.092	1.109	1.126	1.142	1.158	1.174	1.190	1.205
149.	0.966	0.986	1.006	1.025	1.044	1.062	1.080	1.097	1.114	1.131	1.148	1.164	1.179	1.195	1.210
150.	0.971	0.991	1.011	1.030	1.049	1.067	1.085	1.102	1.119	1.136	1.153	1.169	1.185	1.201	1.216
151.	0.975	0.996	1.016	1.035	1.054	1.073	1.090	1.108	1.125	1.142	1.159	1.175	1.191	1.207	1.222
152.	0.980	1.001	1.021	1.040	1.059	1.078	1.096	1.114	1.131	1.148	1.165	1.181	1.197	1.213	1.228
153.	0.985	1.005	1.025	1.045	1.064	1.083	1.101	1.119	1.136	1.153	1.170	1.187	1.203	1.218	1.234
154.	0.989	1.010	1.030	1.050	1.069	1.088	1.106	1.124	1.141	1.158	1.175	1.192	1.208	1.224	1.240
155.	0.994	1.014	1.035	1.055	1.074	1.093	1.111	1.129	1.147	1.164	1.181	1.198	1.214	1.230	1.246
156.	0.999	1.019	1.040	1.060	1.079	1.098	1.116	1.134	1.152	1.169	1.186	1.203	1.220	1.236	1.251
157.	1.003	1.024	1.045	1.065	1.084	1.103	1.121	1.139	1.157	1.175	1.192	1.209	1.225	1.241	1.257
158.	1.008	1.029	1.050	1.070	1.089	1.108	1.127	1.145	1.163	1.181	1.198	1.215	1.231	1.247	1.263
159.	1.013	1.034	1.054	1.074	1.094	1.113	1.132	1.150	1.168	1.186	1.203	1.220	1.237	1.253	1.269
160.	1.017	1.038	1.059	1.079	1.099	1.118	1.137	1.156	1.174	1.192	1.209	1.226	1.243	1.259	1.275
161.	1.022	1.043	1.064	1.084	1.104	1.123	1.142	1.161	1.179	1.197	1.214	1.231	1.248	1.264	1.280
162.	1.026	1.048	1.069	1.089	1.109	1.128	1.147	1.166	1.184	1.202	1.220	1.237	1.253	1.270	1.286
163.	1.031	1.053	1.074	1.094	1.114	1.133	1.152	1.171	1.190	1.208	1.225	1.242	1.259	1.276	1.292
164.	1.036	1.057	1.078	1.099	1.119	1.138	1.157	1.176	1.195	1.213	1.230	1.247	1.264	1.281	1.297
165.	1.040	1.062	1.083	1.104	1.124	1.144	1.163	1.182	1.200	1.218	1.236	1.253	1.270	1.287	1.303
166.	1.045	1.066	1.088	1.109	1.129	1.149	1.168	1.187	1.205	1.223	1.241	1.259	1.276	1.293	1.309
167.	1.049	1.071	1.092	1.113	1.134	1.154	1.173	1.192	1.210	1.229	1.247	1.264	1.281	1.298	1.315
168.	1.054	1.076	1.097	1.118	1.139	1.159	1.178	1.197	1.216	1.234	1.252	1.270	1.287	1.304	1.320
169.	1.058	1.080	1.102	1.123	1.143	1.163	1.183	1.202	1.221	1.239	1.257	1.275	1.292	1.309	1.326
170.	1.062	1.085	1.107	1.128	1.148	1.168	1.188	1.207	1.226	1.245	1.263	1.281	1.298	1.315	1.332
171.	1.067	1.089	1.111	1.132	1.153	1.173	1.193	1.212	1.231	1.250	1.268	1.286	1.303	1.320	1.337
172.	1.072	1.094	1.116	1.137	1.158	1.178	1.198	1.218	1.237	1.255	1.273	1.291	1.309	1.326	1.343
173.	1.076	1.098	1.120	1.141	1.162	1.183	1.203	1.223	1.242	1.260	1.278	1.296	1.314	1.331	1.348
174.	1.080	1.103	1.125	1.146	1.167	1.188	1.208	1.228	1.247	1.265	1.284	1.302	1.320	1.337	1.354

TABLE 295

SURFACE AREA IN SQUARE METERS (DuBois Formula .35 Kg. to 49 Kg., 120 Cm. to 184 Cm.)  
(Stoner, 1926)<sup>17</sup>

Kg. Cm.	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
120.	1.047	1.060	1.073	1.085	1.097	1.109	1.120	1.132	1.143	1.155	1.166	1.176	1.187	1.198	1.209
121.	1.053	1.066	1.079	1.091	1.103	1.115	1.127	1.139	1.150	1.161	1.172	1.183	1.194	1.205	1.216
122.	1.060	1.073	1.085	1.098	1.110	1.122	1.134	1.146	1.157	1.168	1.180	1.191	1.201	1.212	1.223
123.	1.066	1.079	1.092	1.104	1.117	1.129	1.141	1.152	1.164	1.175	1.187	1.198	1.209	1.220	1.231
124.	1.072	1.085	1.098	1.111	1.123	1.135	1.147	1.159	1.171	1.182	1.194	1.205	1.216	1.227	1.238
125.	1.079	1.092	1.105	1.117	1.130	1.142	1.154	1.166	1.178	1.189	1.201	1.212	1.223	1.234	1.245
126.	1.085	1.098	1.111	1.124	1.137	1.149	1.161	1.173	1.184	1.196	1.208	1.219	1.230	1.241	1.252
127.	1.091	1.104	1.117	1.130	1.143	1.156	1.168	1.180	1.191	1.203	1.215	1.226	1.237	1.248	1.259
128.	1.097	1.111	1.124	1.137	1.150	1.162	1.174	1.186	1.198	1.210	1.221	1.233	1.244	1.255	1.266
129.	1.104	1.117	1.130	1.143	1.156	1.168	1.181	1.193	1.205	1.217	1.228	1.240	1.251	1.262	1.273
130.	1.110	1.123	1.137	1.150	1.163	1.175	1.187	1.199	1.211	1.223	1.235	1.247	1.258	1.269	1.281
131.	1.116	1.130	1.143	1.156	1.169	1.182	1.194	1.206	1.218	1.230	1.242	1.254	1.265	1.277	1.288
132.	1.122	1.136	1.149	1.162	1.175	1.188	1.200	1.213	1.225	1.237	1.249	1.261	1.272	1.284	1.295
133.	1.128	1.142	1.156	1.169	1.182	1.195	1.207	1.220	1.232	1.244	1.256	1.268	1.279	1.291	1.302
134.	1.134	1.148	1.162	1.175	1.188	1.201	1.213	1.226	1.238	1.250	1.262	1.274	1.286	1.298	1.309
135.	1.141	1.155	1.168	1.181	1.194	1.207	1.220	1.233	1.245	1.257	1.269	1.281	1.293	1.305	1.316
136.	1.147	1.161	1.174	1.188	1.201	1.214	1.227	1.239	1.252	1.264	1.276	1.288	1.300	1.312	1.323
137.	1.153	1.167	1.181	1.194	1.207	1.220	1.233	1.246	1.258	1.271	1.283	1.295	1.307	1.319	1.330
138.	1.159	1.173	1.187	1.200	1.214	1.227	1.240	1.253	1.265	1.278	1.290	1.302	1.314	1.326	1.337
139.	1.165	1.179	1.193	1.207	1.220	1.233	1.246	1.260	1.272	1.284	1.297	1.309	1.321	1.333	1.344
140.	1.171	1.185	1.199	1.213	1.227	1.240	1.253	1.266	1.278	1.291	1.304	1.316	1.327	1.339	1.351
141.	1.177	1.192	1.206	1.219	1.233	1.246	1.259	1.272	1.285	1.298	1.310	1.323	1.334	1.346	1.358
142.	1.183	1.198	1.212	1.225	1.239	1.253	1.266	1.279	1.292	1.304	1.317	1.329	1.341	1.353	1.365
143.	1.189	1.204	1.218	1.232	1.246	1.259	1.272	1.285	1.298	1.311	1.323	1.336	1.348	1.360	1.372
144.	1.195	1.210	1.224	1.238	1.252	1.265	1.278	1.292	1.305	1.318	1.330	1.343	1.355	1.367	1.379
145.	1.201	1.216	1.230	1.244	1.258	1.272	1.285	1.298	1.311	1.324	1.337	1.350	1.362	1.374	1.386
146.	1.207	1.222	1.237	1.251	1.265	1.278	1.292	1.305	1.318	1.331	1.344	1.356	1.369	1.381	1.393
147.	1.213	1.228	1.243	1.257	1.271	1.284	1.298	1.311	1.324	1.338	1.350	1.363	1.375	1.388	1.400
148.	1.219	1.234	1.249	1.263	1.277	1.291	1.304	1.318	1.331	1.344	1.357	1.370	1.382	1.395	1.407
149.	1.225	1.240	1.255	1.269	1.283	1.297	1.311	1.324	1.338	1.351	1.364	1.377	1.389	1.402	1.414
150.	1.231	1.246	1.261	1.275	1.289	1.303	1.317	1.331	1.344	1.357	1.370	1.383	1.396	1.408	1.421
151.	1.237	1.252	1.267	1.281	1.296	1.310	1.323	1.337	1.351	1.364	1.377	1.390	1.402	1.415	1.428
152.	1.243	1.258	1.273	1.287	1.302	1.316	1.329	1.343	1.357	1.370	1.383	1.396	1.409	1.422	1.434
153.	1.249	1.264	1.279	1.294	1.308	1.322	1.336	1.350	1.363	1.377	1.390	1.403	1.416	1.429	1.441
154.	1.255	1.270	1.285	1.300	1.314	1.328	1.342	1.356	1.370	1.383	1.396	1.409	1.422	1.435	1.448
155.	1.261	1.276	1.291	1.306	1.321	1.335	1.349	1.363	1.376	1.390	1.403	1.416	1.429	1.442	1.455
156.	1.267	1.282	1.297	1.312	1.327	1.341	1.355	1.369	1.383	1.396	1.410	1.423	1.436	1.449	1.462
157.	1.273	1.288	1.303	1.318	1.333	1.347	1.361	1.375	1.389	1.403	1.416	1.429	1.442	1.455	1.468
158.	1.279	1.294	1.309	1.324	1.339	1.354	1.368	1.382	1.396	1.410	1.423	1.436	1.449	1.462	1.475
159.	1.285	1.300	1.315	1.330	1.345	1.360	1.374	1.388	1.402	1.416	1.429	1.443	1.456	1.469	1.482
160.	1.291	1.306	1.321	1.336	1.351	1.366	1.380	1.395	1.409	1.423	1.436	1.450	1.463	1.476	1.489
161.	1.296	1.312	1.327	1.342	1.357	1.372	1.386	1.401	1.415	1.429	1.442	1.456	1.469	1.482	1.495
162.	1.302	1.318	1.333	1.348	1.363	1.378	1.393	1.407	1.421	1.435	1.449	1.463	1.476	1.489	1.502
163.	1.308	1.324	1.339	1.354	1.369	1.384	1.399	1.414	1.428	1.442	1.455	1.469	1.483	1.496	1.509
164.	1.313	1.329	1.345	1.360	1.375	1.390	1.405	1.420	1.434	1.448	1.462	1.475	1.489	1.502	1.516
165.	1.319	1.335	1.351	1.366	1.382	1.397	1.411	1.426	1.440	1.454	1.468	1.482	1.496	1.509	1.522
166.	1.325	1.341	1.357	1.372	1.388	1.403	1.417	1.432	1.446	1.461	1.475	1.489	1.502	1.516	1.529
167.	1.331	1.347	1.363	1.378	1.394	1.409	1.423	1.438	1.452	1.467	1.481	1.495	1.508	1.522	1.536
168.	1.337	1.353	1.369	1.384	1.400	1.415	1.430	1.444	1.459	1.473	1.487	1.501	1.515	1.529	1.542
169.	1.342	1.359	1.375	1.390	1.406	1.421	1.436	1.451	1.465	1.480	1.494	1.508	1.522	1.535	1.548
170.	1.348	1.364	1.380	1.396	1.412	1.427	1.442	1.457	1.471	1.486	1.500	1.514	1.528	1.542	1.555
171.	1.354	1.370	1.386	1.402	1.418	1.433	1.448	1.463	1.478	1.492	1.507	1.521	1.535	1.548	1.562
172.	1.360	1.376	1.392	1.408	1.424	1.439	1.454	1.469	1.484	1.499	1.513	1.527	1.541	1.555	1.569
173.	1.365	1.382	1.398	1.414	1.430	1.445	1.460	1.476	1.490	1.505	1.519	1.533	1.547	1.561	1.575
174.	1.371	1.388	1.404	1.420	1.436	1.451	1.467	1.482	1.497	1.511	1.526	1.540	1.554	1.568	1.582
175.	1.377	1.393	1.410	1.426	1.442	1.457	1.473	1.488	1.503	1.518	1.532	1.547	1.561	1.575	1.589
176.	1.383	1.399	1.416	1.432	1.448	1.464	1.479	1.494	1.509	1.524	1.539	1.553	1.567	1.581	1.595
177.	1.388	1.405	1.422	1.438	1.454	1.470	1.485	1.500	1.515	1.530	1.545	1.560	1.574	1.588	1.602
178.	1.394	1.411	1.428	1.444	1.460	1.476	1.491	1.507	1.522	1.537	1.552	1.566	1.581	1.595	1.609
179.	1.400	1.417	1.434	1.450	1.466	1.482	1.497	1.513	1.528	1.543	1.558	1.573	1.587	1.601	1.615
180.	1.405	1.422	1.439	1.455	1.471	1.487	1.503	1.518	1.534	1.549	1.564	1.579	1.593	1.607	1.621
181.	1.411	1.428	1.445	1.461	1.477	1.493	1.509	1.525	1.540	1.555	1.570	1.585	1.599	1.614	1.628
182.	1.417	1.434	1.451	1.467	1.483	1.499	1.515	1.531	1.546	1.561	1.576	1.591	1.606	1.620	1.634
183.	1.422	1.439	1.456	1.473	1.489	1.505	1.521	1.537	1.552	1.567	1.582	1.597	1.612	1.626	1.641
184.	1.428	1.445	1.462	1.479	1.495	1.511	1.527	1.543	1.558	1.574	1.589	1.604	1.618	1.633	1.647

TABLE 296

SURFACE AREA IN SQUARE METERS (DuBois Formula). 50 KG. TO 64 KG., 135 CM. TO 199 CM.  
(Stoner, 1926)<sup>17</sup>

kg cm	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
135	1.327	1.338	1.349	1.361	1.372	1.383	1.393	1.404	1.414	1.424	1.434	1.445	1.455	1.465	1.475
136	1.335	1.346	1.357	1.368	1.379	1.390	1.401	1.411	1.421	1.432	1.442	1.452	1.463	1.472	1.482
137	1.342	1.353	1.364	1.375	1.386	1.397	1.408	1.419	1.429	1.439	1.450	1.460	1.470	1.480	1.490
138	1.349	1.360	1.371	1.383	1.394	1.405	1.415	1.426	1.436	1.447	1.457	1.468	1.478	1.488	1.498
139	1.356	1.367	1.378	1.390	1.401	1.412	1.423	1.434	1.444	1.455	1.465	1.476	1.486	1.496	1.506
140	1.363	1.374	1.385	1.397	1.408	1.419	1.430	1.441	1.451	1.462	1.473	1.483	1.493	1.503	1.514
141	1.370	1.381	1.393	1.404	1.416	1.427	1.438	1.449	1.459	1.470	1.480	1.491	1.501	1.511	1.522
142	1.377	1.388	1.400	1.412	1.423	1.434	1.445	1.456	1.467	1.477	1.488	1.499	1.509	1.519	1.529
143	1.384	1.395	1.407	1.419	1.430	1.441	1.452	1.463	1.474	1.485	1.496	1.506	1.517	1.527	1.537
144	1.391	1.402	1.414	1.426	1.437	1.449	1.460	1.471	1.482	1.492	1.503	1.514	1.524	1.535	1.545
145	1.398	1.410	1.421	1.433	1.445	1.456	1.467	1.478	1.489	1.500	1.511	1.522	1.532	1.542	1.553
146	1.405	1.417	1.428	1.440	1.452	1.464	1.475	1.486	1.497	1.508	1.518	1.529	1.540	1.550	1.561
147	1.412	1.424	1.435	1.447	1.459	1.471	1.482	1.493	1.504	1.515	1.526	1.537	1.547	1.558	1.568
148	1.419	1.431	1.443	1.455	1.467	1.478	1.489	1.500	1.511	1.523	1.534	1.545	1.555	1.566	1.576
149	1.426	1.438	1.450	1.462	1.474	1.485	1.497	1.508	1.519	1.530	1.541	1.552	1.563	1.573	1.584
150	1.433	1.445	1.457	1.469	1.481	1.492	1.504	1.515	1.526	1.537	1.548	1.559	1.570	1.581	1.591
151	1.440	1.452	1.464	1.476	1.488	1.500	1.511	1.523	1.534	1.545	1.556	1.567	1.578	1.589	1.599
152	1.447	1.459	1.471	1.483	1.495	1.507	1.518	1.530	1.541	1.552	1.563	1.574	1.585	1.596	1.607
153	1.454	1.466	1.478	1.490	1.502	1.514	1.525	1.537	1.548	1.560	1.571	1.582	1.593	1.604	1.614
154	1.461	1.473	1.485	1.497	1.509	1.521	1.532	1.544	1.555	1.567	1.578	1.589	1.600	1.611	1.622
155	1.468	1.480	1.492	1.504	1.516	1.528	1.540	1.552	1.563	1.574	1.586	1.597	1.608	1.619	1.630
156	1.474	1.486	1.498	1.511	1.523	1.535	1.547	1.559	1.570	1.582	1.593	1.604	1.615	1.626	1.637
157	1.481	1.493	1.505	1.518	1.530	1.542	1.554	1.566	1.577	1.589	1.600	1.612	1.623	1.634	1.645
158	1.488	1.500	1.512	1.525	1.538	1.550	1.562	1.573	1.585	1.596	1.608	1.620	1.631	1.642	1.653
159	1.495	1.507	1.519	1.532	1.545	1.557	1.569	1.581	1.592	1.604	1.615	1.627	1.638	1.649	1.660
160	1.502	1.514	1.526	1.539	1.552	1.564	1.576	1.588	1.599	1.611	1.623	1.635	1.646	1.657	1.668
161	1.508	1.521	1.533	1.546	1.559	1.571	1.583	1.595	1.606	1.618	1.630	1.641	1.653	1.664	1.675
162	1.515	1.528	1.540	1.553	1.566	1.578	1.590	1.602	1.614	1.626	1.637	1.649	1.660	1.671	1.683
163	1.522	1.535	1.547	1.560	1.573	1.585	1.597	1.609	1.621	1.633	1.645	1.657	1.668	1.679	1.690
164	1.529	1.541	1.554	1.567	1.580	1.592	1.604	1.616	1.628	1.640	1.652	1.664	1.675	1.686	1.697
165	1.535	1.548	1.561	1.574	1.587	1.599	1.611	1.624	1.635	1.647	1.659	1.671	1.683	1.694	1.705
166	1.542	1.555	1.568	1.581	1.594	1.606	1.618	1.631	1.642	1.654	1.666	1.678	1.690	1.701	1.713
167	1.549	1.561	1.574	1.587	1.600	1.613	1.625	1.638	1.649	1.661	1.673	1.685	1.697	1.708	1.720
168	1.555	1.568	1.581	1.594	1.607	1.620	1.632	1.645	1.657	1.669	1.681	1.693	1.705	1.716	1.727
169	1.562	1.575	1.588	1.601	1.614	1.627	1.639	1.652	1.664	1.676	1.688	1.700	1.712	1.723	1.735
170	1.569	1.582	1.595	1.608	1.621	1.634	1.646	1.659	1.671	1.683	1.695	1.707	1.719	1.731	1.742
171	1.576	1.589	1.602	1.615	1.628	1.641	1.653	1.666	1.678	1.690	1.703	1.715	1.727	1.738	1.750
172	1.583	1.596	1.609	1.622	1.635	1.648	1.660	1.673	1.686	1.698	1.710	1.722	1.734	1.745	1.757
173	1.589	1.602	1.615	1.628	1.642	1.655	1.667	1.680	1.693	1.705	1.717	1.729	1.741	1.753	1.765
174	1.596	1.609	1.622	1.635	1.649	1.662	1.675	1.687	1.699	1.712	1.724	1.737	1.749	1.760	1.772
175	1.603	1.616	1.629	1.642	1.656	1.669	1.682	1.694	1.706	1.719	1.731	1.744	1.756	1.768	1.780
176	1.609	1.622	1.635	1.649	1.663	1.676	1.689	1.701	1.713	1.726	1.739	1.751	1.763	1.775	1.787
177	1.616	1.629	1.642	1.656	1.670	1.683	1.696	1.708	1.720	1.733	1.746	1.758	1.771	1.782	1.794
178	1.623	1.636	1.649	1.663	1.677	1.690	1.703	1.715	1.728	1.740	1.753	1.766	1.778	1.790	1.802
179	1.629	1.642	1.656	1.670	1.683	1.697	1.710	1.722	1.735	1.747	1.760	1.773	1.785	1.797	1.809
180	1.635	1.649	1.662	1.676	1.690	1.703	1.716	1.729	1.742	1.754	1.767	1.780	1.792	1.804	1.816
181	1.642	1.655	1.669	1.683	1.697	1.710	1.723	1.736	1.749	1.762	1.774	1.787	1.799	1.811	1.823
182	1.649	1.662	1.676	1.690	1.704	1.717	1.730	1.743	1.756	1.769	1.781	1.794	1.806	1.819	1.831
183	1.655	1.668	1.682	1.696	1.710	1.723	1.737	1.750	1.763	1.776	1.788	1.801	1.813	1.826	1.838
184	1.661	1.675	1.689	1.703	1.717	1.730	1.744	1.757	1.770	1.783	1.796	1.808	1.821	1.833	1.845
185	1.668	1.682	1.696	1.710	1.724	1.737	1.751	1.764	1.777	1.790	1.803	1.816	1.828	1.840	1.853
186	1.675	1.688	1.702	1.717	1.731	1.744	1.758	1.771	1.784	1.797	1.810	1.823	1.835	1.848	1.860
187	1.681	1.695	1.709	1.723	1.737	1.751	1.764	1.778	1.791	1.804	1.817	1.830	1.842	1.855	1.867
188	1.688	1.702	1.716	1.730	1.744	1.758	1.771	1.785	1.798	1.811	1.824	1.837	1.849	1.862	1.875
189	1.695	1.708	1.722	1.737	1.751	1.765	1.778	1.792	1.805	1.818	1.831	1.844	1.856	1.869	1.882
190	1.701	1.715	1.729	1.743	1.758	1.771	1.785	1.798	1.811	1.825	1.838	1.851	1.863	1.876	1.889
191	1.707	1.721	1.735	1.750	1.764	1.778	1.791	1.805	1.818	1.832	1.845	1.858	1.870	1.883	1.896
192	1.714	1.728	1.742	1.757	1.771	1.785	1.798	1.812	1.825	1.839	1.852	1.865	1.878	1.891	1.903
193	1.721	1.735	1.749	1.764	1.778	1.792	1.805	1.819	1.832	1.846	1.859	1.872	1.885	1.898	1.911
194	1.727	1.741	1.755	1.770	1.784	1.798	1.812	1.826	1.839	1.853	1.866	1.879	1.892	1.905	1.918
195	1.733	1.747	1.762	1.777	1.791	1.805	1.819	1.833	1.846	1.860	1.873	1.886	1.899	1.912	1.925
196	1.740	1.754	1.768	1.783	1.798	1.812	1.826	1.840	1.853	1.866	1.880	1.893	1.906	1.919	1.932
197	1.746	1.760	1.775	1.790	1.804	1.818	1.832	1.846	1.860	1.873	1.887	1.900	1.913	1.926	1.939
198	1.752	1.767	1.781	1.796	1.811	1.825	1.839	1.853	1.866	1.880	1.894	1.907	1.920	1.933	1.946
199	1.758	1.773	1.788	1.803	1.818	1.832	1.846	1.860	1.873	1.887	1.900	1.913	1.926	1.940	1.953

TABLE 297

SURFACE AREA IN SQUARE METERS (DuBois Formula). 65 KG. TO 79 KG., 135 CM. TO 199 CM.  
(Stoner, 1926)<sup>17</sup>

Kg. Cm.	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79
135.	1.484	1.494	1.503	1.513	1.522	1.532	1.541	1.550	1.559	1.568	1.577	1.586	1.595	1.604	1.613
136.	1.492	1.502	1.511	1.521	1.530	1.540	1.549	1.558	1.567	1.577	1.586	1.595	1.604	1.612	1.621
137.	1.500	1.510	1.519	1.529	1.539	1.548	1.557	1.567	1.576	1.585	1.594	1.603	1.612	1.621	1.630
138.	1.508	1.518	1.528	1.537	1.547	1.556	1.566	1.575	1.584	1.593	1.603	1.611	1.620	1.629	1.638
139.	1.516	1.526	1.536	1.545	1.555	1.565	1.574	1.583	1.593	1.602	1.611	1.620	1.629	1.638	1.647
140.	1.524	1.534	1.544	1.553	1.563	1.573	1.582	1.591	1.601	1.610	1.619	1.628	1.637	1.646	1.655
141.	1.532	1.542	1.552	1.561	1.571	1.581	1.590	1.600	1.609	1.618	1.628	1.637	1.646	1.655	1.664
142.	1.540	1.550	1.560	1.569	1.579	1.589	1.598	1.608	1.617	1.627	1.636	1.645	1.654	1.663	1.672
143.	1.547	1.557	1.567	1.577	1.587	1.597	1.607	1.616	1.625	1.635	1.644	1.653	1.663	1.672	1.681
144.	1.555	1.565	1.575	1.585	1.595	1.605	1.615	1.624	1.634	1.643	1.653	1.662	1.671	1.680	1.689
145.	1.563	1.573	1.583	1.593	1.603	1.613	1.623	1.633	1.642	1.652	1.661	1.670	1.680	1.689	1.698
146.	1.571	1.581	1.591	1.601	1.611	1.621	1.631	1.641	1.650	1.660	1.670	1.679	1.688	1.697	1.706
147.	1.579	1.589	1.599	1.609	1.619	1.629	1.639	1.649	1.658	1.668	1.678	1.687	1.697	1.706	1.715
148.	1.587	1.597	1.607	1.617	1.627	1.637	1.647	1.657	1.667	1.676	1.686	1.696	1.705	1.714	1.724
149.	1.594	1.605	1.615	1.625	1.635	1.645	1.655	1.665	1.675	1.685	1.694	1.704	1.714	1.723	1.732
150.	1.602	1.613	1.623	1.633	1.643	1.653	1.663	1.673	1.683	1.693	1.703	1.712	1.722	1.731	1.741
151.	1.610	1.620	1.631	1.641	1.651	1.661	1.671	1.681	1.691	1.701	1.711	1.720	1.730	1.739	1.749
152.	1.617	1.628	1.638	1.649	1.659	1.669	1.679	1.689	1.699	1.709	1.719	1.728	1.738	1.747	1.757
153.	1.625	1.636	1.646	1.657	1.667	1.677	1.687	1.697	1.707	1.717	1.727	1.737	1.747	1.756	1.766
154.	1.633	1.643	1.654	1.664	1.675	1.685	1.695	1.705	1.715	1.725	1.735	1.745	1.755	1.764	1.774
155.	1.641	1.651	1.662	1.672	1.683	1.693	1.703	1.713	1.723	1.733	1.743	1.753	1.763	1.773	1.782
156.	1.648	1.659	1.670	1.680	1.690	1.701	1.711	1.721	1.731	1.741	1.751	1.761	1.771	1.781	1.791
157.	1.656	1.666	1.677	1.688	1.698	1.709	1.719	1.729	1.739	1.749	1.760	1.770	1.780	1.789	1.799
158.	1.664	1.675	1.685	1.696	1.706	1.717	1.727	1.737	1.747	1.758	1.768	1.778	1.788	1.798	1.808
159.	1.671	1.682	1.693	1.703	1.714	1.725	1.735	1.745	1.755	1.766	1.776	1.786	1.796	1.806	1.816
160.	1.679	1.690	1.701	1.711	1.722	1.733	1.743	1.753	1.763	1.774	1.784	1.794	1.804	1.814	1.824
161.	1.686	1.697	1.708	1.719	1.729	1.740	1.751	1.761	1.771	1.782	1.792	1.802	1.812	1.822	1.832
162.	1.694	1.705	1.716	1.727	1.737	1.748	1.759	1.769	1.780	1.790	1.800	1.810	1.820	1.830	1.840
163.	1.702	1.713	1.724	1.735	1.745	1.756	1.767	1.777	1.788	1.798	1.808	1.818	1.829	1.839	1.849
164.	1.709	1.720	1.731	1.742	1.753	1.764	1.774	1.785	1.795	1.806	1.816	1.826	1.837	1.847	1.857
165.	1.717	1.728	1.739	1.750	1.761	1.772	1.782	1.793	1.803	1.814	1.824	1.834	1.845	1.855	1.865
166.	1.724	1.735	1.747	1.758	1.769	1.780	1.790	1.801	1.811	1.822	1.832	1.842	1.853	1.863	1.873
167.	1.731	1.743	1.754	1.765	1.776	1.787	1.798	1.808	1.819	1.829	1.840	1.850	1.861	1.871	1.881
168.	1.739	1.750	1.762	1.773	1.784	1.795	1.806	1.816	1.827	1.837	1.848	1.858	1.869	1.879	1.889
169.	1.747	1.758	1.769	1.780	1.791	1.802	1.813	1.824	1.835	1.845	1.856	1.866	1.877	1.887	1.897
170.	1.754	1.765	1.777	1.788	1.799	1.810	1.821	1.832	1.843	1.853	1.864	1.874	1.885	1.895	1.905
171.	1.762	1.773	1.785	1.796	1.807	1.818	1.829	1.840	1.851	1.861	1.872	1.882	1.893	1.903	1.914
172.	1.769	1.781	1.792	1.803	1.814	1.826	1.837	1.848	1.859	1.869	1.880	1.890	1.901	1.912	1.922
173.	1.777	1.788	1.799	1.810	1.821	1.833	1.844	1.855	1.866	1.877	1.888	1.898	1.909	1.920	1.930
174.	1.784	1.796	1.807	1.818	1.829	1.841	1.852	1.863	1.874	1.885	1.896	1.906	1.917	1.928	1.938
175.	1.791	1.803	1.815	1.826	1.837	1.849	1.860	1.871	1.882	1.893	1.904	1.914	1.925	1.936	1.946
176.	1.799	1.811	1.822	1.834	1.845	1.857	1.868	1.879	1.890	1.901	1.912	1.922	1.933	1.944	1.954
177.	1.806	1.818	1.830	1.841	1.853	1.864	1.876	1.887	1.898	1.909	1.920	1.930	1.941	1.952	1.962
178.	1.814	1.826	1.838	1.849	1.861	1.872	1.884	1.895	1.906	1.917	1.928	1.938	1.949	1.960	1.971
179.	1.821	1.833	1.845	1.857	1.868	1.880	1.891	1.902	1.913	1.924	1.935	1.946	1.957	1.968	1.979
180.	1.828	1.840	1.852	1.864	1.875	1.887	1.898	1.909	1.920	1.932	1.943	1.954	1.965	1.975	1.986
181.	1.836	1.848	1.860	1.871	1.883	1.895	1.906	1.917	1.928	1.940	1.951	1.962	1.973	1.983	1.994
182.	1.843	1.855	1.867	1.879	1.891	1.902	1.914	1.925	1.936	1.948	1.959	1.970	1.981	1.991	2.002
183.	1.850	1.862	1.874	1.886	1.898	1.909	1.921	1.932	1.944	1.955	1.966	1.977	1.988	1.999	2.010
184.	1.858	1.870	1.882	1.894	1.905	1.917	1.929	1.940	1.952	1.963	1.974	1.985	1.996	2.007	2.018
185.	1.865	1.877	1.889	1.901	1.913	1.925	1.936	1.948	1.959	1.971	1.982	1.993	2.004	2.015	2.026
186.	1.872	1.885	1.897	1.909	1.921	1.932	1.944	1.956	1.967	1.978	1.990	2.001	2.012	2.023	2.034
187.	1.879	1.892	1.904	1.916	1.928	1.940	1.951	1.963	1.974	1.986	1.997	2.008	2.020	2.031	2.042
188.	1.887	1.899	1.912	1.924	1.936	1.948	1.959	1.971	1.982	1.994	2.005	2.016	2.028	2.039	2.050
189.	1.895	1.907	1.919	1.931	1.943	1.955	1.967	1.979	1.990	2.002	2.013	2.024	2.036	2.047	2.058
190.	1.902	1.914	1.926	1.938	1.950	1.962	1.974	1.986	1.998	2.009	2.021	2.032	2.044	2.055	2.066
191.	1.909	1.921	1.933	1.945	1.957	1.970	1.982	1.994	2.005	2.017	2.028	2.039	2.051	2.062	2.073
192.	1.916	1.928	1.941	1.953	1.965	1.977	1.989	2.001	2.013	2.024	2.036	2.047	2.059	2.070	2.081
193.	1.924	1.936	1.948	1.961	1.973	1.985	1.997	2.009	2.021	2.032	2.044	2.055	2.067	2.078	2.089
194.	1.931	1.943	1.956	1.968	1.980	1.992	2.004	2.016	2.028	2.040	2.052	2.063	2.075	2.086	2.097
195.	1.938	1.950	1.963	1.975	1.987	2.000	2.012	2.024	2.036	2.047	2.059	2.071	2.083	2.094	2.105
196.	1.945	1.957	1.970	1.982	1.995	2.007	2.019	2.031	2.043	2.055	2.067	2.078	2.090	2.101	2.113
197.	1.952	1.965	1.977	1.990	2.002	2.015	2.027	2.039	2.051	2.063	2.074	2.086	2.097	2.109	2.121
198.	1.959	1.972	1.985	1.997	2.010	2.022	2.034	2.046	2.058	2.070	2.082	2.094	2.105	2.117	2.129
199.	1.966	1.979	1.992	2.004	2.017	2.030	2.042	2.054	2.066	2.078	2.090	2.101	2.113	2.125	2.137

TABLE 298

SURFACE AREA IN SQUARE METERS (DuBois Formula) . 80 KG. TO 94 KG., 135 CM. TO 199 CM.  
(Stoner, 1926)<sup>17</sup>

KG.	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
35	1.621	1.629	1.638	1.647	1.655	1.664	1.672	1.680	1.688	1.696	1.704	1.712	1.720	1.728	1.736
36	1.630	1.638	1.647	1.655	1.664	1.673	1.681	1.689	1.697	1.705	1.713	1.721	1.729	1.737	1.745
37	1.638	1.646	1.655	1.664	1.673	1.682	1.690	1.698	1.706	1.714	1.722	1.731	1.739	1.747	1.755
38	1.647	1.655	1.664	1.673	1.682	1.690	1.699	1.707	1.715	1.723	1.731	1.740	1.748	1.756	1.764
39	1.656	1.664	1.673	1.682	1.690	1.699	1.708	1.716	1.724	1.733	1.741	1.749	1.757	1.765	1.773
40	1.664	1.672	1.681	1.690	1.699	1.708	1.717	1.725	1.733	1.742	1.750	1.758	1.766	1.774	1.782
41	1.673	1.681	1.690	1.699	1.708	1.717	1.726	1.734	1.742	1.751	1.759	1.767	1.775	1.784	1.792
42	1.682	1.690	1.699	1.708	1.717	1.726	1.734	1.743	1.751	1.760	1.768	1.776	1.784	1.793	1.801
43	1.690	1.699	1.708	1.717	1.725	1.735	1.743	1.751	1.760	1.769	1.777	1.785	1.793	1.802	1.810
44	1.699	1.707	1.716	1.725	1.734	1.743	1.752	1.760	1.769	1.778	1.786	1.794	1.803	1.811	1.819
45	1.707	1.716	1.725	1.734	1.743	1.752	1.761	1.769	1.778	1.787	1.795	1.803	1.812	1.820	1.828
46	1.716	1.725	1.734	1.743	1.752	1.761	1.770	1.778	1.787	1.796	1.804	1.813	1.821	1.829	1.837
47	1.724	1.733	1.742	1.751	1.760	1.770	1.778	1.787	1.796	1.805	1.813	1.822	1.830	1.838	1.846
48	1.733	1.742	1.751	1.760	1.769	1.779	1.787	1.796	1.805	1.814	1.822	1.831	1.839	1.848	1.856
49	1.741	1.750	1.760	1.769	1.778	1.787	1.796	1.805	1.813	1.822	1.831	1.840	1.848	1.857	1.865
50	1.750	1.759	1.768	1.777	1.786	1.796	1.805	1.814	1.822	1.831	1.840	1.848	1.857	1.866	1.874
51	1.758	1.767	1.777	1.786	1.795	1.805	1.814	1.823	1.831	1.840	1.848	1.857	1.866	1.875	1.883
52	1.766	1.775	1.785	1.794	1.803	1.813	1.822	1.831	1.840	1.849	1.857	1.866	1.875	1.883	1.892
53	1.775	1.784	1.794	1.803	1.812	1.822	1.831	1.840	1.848	1.857	1.866	1.875	1.884	1.892	1.901
54	1.783	1.792	1.802	1.811	1.821	1.830	1.839	1.848	1.857	1.866	1.875	1.884	1.893	1.901	1.910
55	1.792	1.801	1.811	1.820	1.829	1.839	1.848	1.857	1.866	1.875	1.884	1.893	1.902	1.910	1.919
56	1.800	1.809	1.819	1.829	1.838	1.848	1.857	1.866	1.875	1.884	1.893	1.902	1.910	1.919	1.928
57	1.808	1.818	1.828	1.837	1.846	1.856	1.865	1.874	1.883	1.892	1.901	1.910	1.919	1.928	1.937
58	1.817	1.827	1.837	1.846	1.855	1.865	1.874	1.883	1.892	1.901	1.910	1.919	1.928	1.937	1.946
59	1.825	1.835	1.845	1.854	1.863	1.873	1.882	1.891	1.901	1.910	1.919	1.928	1.937	1.946	1.955
60	1.834	1.844	1.854	1.863	1.872	1.882	1.891	1.900	1.910	1.919	1.928	1.937	1.946	1.955	1.964
61	1.842	1.852	1.862	1.871	1.880	1.890	1.899	1.909	1.918	1.927	1.936	1.945	1.954	1.963	1.972
62	1.850	1.860	1.870	1.879	1.889	1.899	1.908	1.917	1.927	1.936	1.945	1.954	1.963	1.972	1.981
63	1.859	1.868	1.878	1.888	1.898	1.908	1.917	1.926	1.936	1.945	1.954	1.963	1.972	1.981	1.990
64	1.867	1.876	1.886	1.896	1.906	1.916	1.925	1.934	1.944	1.953	1.962	1.972	1.981	1.990	1.999
65	1.875	1.885	1.895	1.905	1.914	1.924	1.934	1.943	1.953	1.962	1.971	1.981	1.990	1.999	2.008
66	1.883	1.893	1.903	1.913	1.923	1.933	1.942	1.952	1.961	1.971	1.980	1.989	1.998	2.008	2.017
67	1.891	1.901	1.911	1.921	1.931	1.941	1.950	1.960	1.969	1.979	1.988	1.998	2.007	2.016	2.025
68	1.899	1.909	1.920	1.930	1.939	1.949	1.959	1.968	1.978	1.988	1.997	2.006	2.016	2.025	2.034
69	1.908	1.918	1.928	1.938	1.948	1.958	1.967	1.977	1.987	1.996	2.005	2.015	2.024	2.034	2.043
70	1.916	1.926	1.936	1.946	1.956	1.966	1.976	1.985	1.995	2.005	2.014	2.023	2.033	2.042	2.051
71	1.924	1.934	1.944	1.954	1.964	1.974	1.984	1.994	2.004	2.014	2.023	2.032	2.042	2.051	2.060
72	1.932	1.942	1.953	1.963	1.973	1.983	1.993	2.003	2.012	2.022	2.031	2.041	2.051	2.060	2.069
73	1.940	1.950	1.961	1.971	1.981	1.991	2.001	2.011	2.020	2.030	2.039	2.049	2.059	2.068	2.077
74	1.948	1.958	1.969	1.979	1.989	2.000	2.010	2.019	2.029	2.039	2.048	2.058	2.068	2.077	2.086
75	1.957	1.967	1.977	1.987	1.998	2.008	2.018	2.028	2.038	2.048	2.057	2.067	2.076	2.086	2.095
76	1.965	1.975	1.986	1.996	2.006	2.017	2.026	2.036	2.046	2.056	2.065	2.075	2.085	2.095	2.104
77	1.973	1.983	1.994	2.004	2.014	2.025	2.035	2.045	2.055	2.064	2.074	2.084	2.094	2.103	2.113
78	1.981	1.991	2.002	2.012	2.023	2.034	2.044	2.054	2.063	2.073	2.083	2.093	2.103	2.112	2.122
79	1.989	1.999	2.010	2.020	2.031	2.042	2.052	2.062	2.072	2.082	2.091	2.101	2.111	2.121	2.130
80	1.997	2.007	2.018	2.028	2.039	2.050	2.060	2.070	2.080	2.090	2.099	2.109	2.119	2.129	2.138
81	2.005	2.015	2.026	2.037	2.047	2.058	2.068	2.078	2.088	2.098	2.108	2.118	2.128	2.137	2.147
82	2.013	2.023	2.034	2.045	2.055	2.066	2.076	2.086	2.097	2.107	2.116	2.126	2.136	2.146	2.156
83	2.021	2.031	2.042	2.053	2.063	2.074	2.084	2.094	2.105	2.115	2.124	2.134	2.144	2.154	2.164
84	2.029	2.040	2.051	2.061	2.072	2.083	2.093	2.103	2.113	2.123	2.133	2.143	2.153	2.163	2.173
85	2.037	2.048	2.059	2.069	2.080	2.091	2.101	2.111	2.121	2.131	2.141	2.152	2.162	2.171	2.181
86	2.045	2.056	2.067	2.077	2.088	2.099	2.109	2.119	2.130	2.140	2.150	2.160	2.170	2.180	2.190
87	2.053	2.064	2.075	2.085	2.096	2.107	2.117	2.127	2.138	2.148	2.158	2.168	2.178	2.188	2.198
88	2.061	2.072	2.083	2.094	2.104	2.115	2.126	2.136	2.146	2.157	2.167	2.177	2.187	2.197	2.207
89	2.069	2.080	2.091	2.102	2.112	2.123	2.134	2.144	2.155	2.165	2.175	2.186	2.196	2.206	2.216
90	2.077	2.088	2.099	2.110	2.120	2.131	2.142	2.152	2.163	2.173	2.183	2.194	2.204	2.214	2.224
91	2.085	2.096	2.107	2.118	2.128	2.139	2.150	2.160	2.171	2.181	2.191	2.202	2.212	2.222	2.232
92	2.093	2.104	2.115	2.126	2.136	2.147	2.158	2.169	2.179	2.190	2.200	2.211	2.221	2.231	2.241
93	2.101	2.112	2.123	2.134	2.145	2.156	2.167	2.177	2.188	2.199	2.209	2.219	2.229	2.240	2.250
94	2.109	2.120	2.131	2.142	2.153	2.164	2.175	2.185	2.196	2.207	2.217	2.227	2.238	2.248	2.258
95	2.116	2.127	2.139	2.150	2.161	2.172	2.183	2.193	2.204	2.215	2.225	2.236	2.246	2.256	2.266
96	2.124	2.135	2.147	2.158	2.169	2.180	2.191	2.201	2.212	2.223	2.233	2.244	2.254	2.265	2.275
97	2.132	2.143	2.155	2.166	2.177	2.188	2.199	2.210	2.220	2.231	2.241	2.252	2.263	2.273	2.283
98	2.140	2.151	2.163	2.174	2.185	2.196	2.207	2.218	2.228	2.239	2.250	2.260	2.271	2.281	2.291
99	2.148	2.159	2.171	2.182	2.193	2.204	2.215	2.226	2.237	2.248	2.258	2.269	2.279	2.290	2.300

TABLE 299

SURFACE AREA IN SQUARE METERS (DuBois Formula). 95 KG. TO 109 KG., 135 CM. TO 199 CM.  
(Stoner, 1926)<sup>17</sup>

kg. Cm.	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109
135.	1.744	1.752	1.760	1.767	1.775	1.782	1.790	1.798	1.805	1.812	1.820	1.827	1.834	1.842	1.849
136.	1.753	1.761	1.769	1.777	1.784	1.792	1.799	1.807	1.814	1.822	1.829	1.837	1.844	1.851	1.858
137.	1.763	1.771	1.778	1.786	1.793	1.801	1.809	1.817	1.824	1.831	1.839	1.847	1.854	1.861	1.868
138.	1.772	1.780	1.788	1.796	1.803	1.811	1.818	1.826	1.834	1.841	1.849	1.857	1.864	1.871	1.878
139.	1.781	1.789	1.797	1.805	1.813	1.821	1.828	1.836	1.843	1.851	1.859	1.866	1.874	1.881	1.888
140.	1.790	1.798	1.806	1.814	1.822	1.830	1.837	1.845	1.853	1.860	1.868	1.876	1.883	1.891	1.898
141.	1.800	1.808	1.816	1.824	1.831	1.840	1.847	1.855	1.863	1.870	1.878	1.886	1.893	1.901	1.908
142.	1.809	1.817	1.825	1.833	1.841	1.849	1.857	1.865	1.872	1.880	1.888	1.895	1.903	1.910	1.917
143.	1.818	1.826	1.834	1.842	1.850	1.858	1.866	1.874	1.881	1.889	1.897	1.905	1.912	1.920	1.927
144.	1.827	1.836	1.844	1.852	1.860	1.868	1.875	1.884	1.891	1.899	1.907	1.915	1.922	1.930	1.937
145.	1.837	1.845	1.853	1.861	1.869	1.877	1.885	1.893	1.901	1.909	1.916	1.924	1.932	1.940	1.947
146.	1.846	1.854	1.863	1.871	1.879	1.887	1.895	1.903	1.910	1.918	1.926	1.934	1.942	1.949	1.957
147.	1.855	1.863	1.872	1.880	1.888	1.896	1.904	1.912	1.920	1.928	1.936	1.944	1.951	1.959	1.967
148.	1.864	1.873	1.881	1.889	1.897	1.905	1.913	1.921	1.929	1.937	1.945	1.953	1.961	1.969	1.977
149.	1.873	1.882	1.890	1.898	1.906	1.915	1.923	1.931	1.939	1.947	1.955	1.963	1.971	1.979	1.986
150.	1.882	1.891	1.899	1.908	1.916	1.924	1.932	1.940	1.948	1.956	1.964	1.972	1.980	1.988	1.996
151.	1.891	1.900	1.909	1.917	1.925	1.933	1.941	1.949	1.957	1.966	1.974	1.982	1.990	1.998	2.006
152.	1.900	1.909	1.918	1.926	1.934	1.942	1.950	1.959	1.967	1.975	1.983	1.991	1.999	2.007	2.015
153.	1.909	1.918	1.927	1.935	1.943	1.952	1.960	1.968	1.976	1.984	1.993	2.001	2.009	2.017	2.024
154.	1.918	1.927	1.936	1.944	1.952	1.961	1.969	1.977	1.985	1.993	2.002	2.010	2.018	2.026	2.034
155.	1.927	1.936	1.945	1.953	1.962	1.970	1.978	1.987	1.995	2.003	2.011	2.020	2.028	2.036	2.044
156.	1.936	1.945	1.954	1.962	1.971	1.979	1.987	1.996	2.004	2.012	2.021	2.029	2.037	2.045	2.053
157.	1.945	1.954	1.963	1.972	1.980	1.988	1.997	2.005	2.013	2.022	2.030	2.038	2.046	2.054	2.063
158.	1.955	1.963	1.972	1.981	1.989	1.998	2.006	2.015	2.023	2.031	2.040	2.048	2.056	2.064	2.073
159.	1.964	1.972	1.981	1.990	1.998	2.007	2.015	2.024	2.032	2.040	2.049	2.057	2.065	2.073	2.082
160.	1.973	1.981	1.990	1.999	2.007	2.016	2.024	2.033	2.042	2.050	2.059	2.067	2.075	2.083	2.091
161.	1.981	1.990	1.999	2.008	2.016	2.025	2.033	2.042	2.051	2.059	2.068	2.076	2.084	2.092	2.100
162.	1.990	1.999	2.008	2.017	2.025	2.034	2.043	2.052	2.060	2.068	2.077	2.085	2.094	2.102	2.110
163.	1.999	2.009	2.017	2.026	2.034	2.043	2.052	2.061	2.069	2.078	2.086	2.095	2.103	2.112	2.120
164.	2.008	2.017	2.026	2.035	2.043	2.052	2.061	2.070	2.078	2.087	2.095	2.104	2.112	2.121	2.129
165.	2.017	2.026	2.035	2.044	2.052	2.061	2.070	2.079	2.087	2.096	2.105	2.113	2.122	2.130	2.138
166.	2.026	2.035	2.044	2.053	2.061	2.070	2.079	2.088	2.096	2.105	2.114	2.123	2.131	2.139	2.148
167.	2.034	2.044	2.053	2.062	2.070	2.079	2.088	2.097	2.105	2.114	2.123	2.132	2.140	2.148	2.157
168.	2.043	2.053	2.062	2.071	2.079	2.088	2.097	2.106	2.114	2.123	2.132	2.141	2.149	2.158	2.166
169.	2.052	2.062	2.071	2.080	2.088	2.097	2.106	2.115	2.124	2.132	2.141	2.150	2.159	2.167	2.176
170.	2.061	2.070	2.079	2.088	2.097	2.106	2.115	2.124	2.133	2.141	2.150	2.159	2.168	2.176	2.185
171.	2.070	2.079	2.088	2.098	2.106	2.115	2.124	2.133	2.142	2.151	2.160	2.169	2.177	2.186	2.194
172.	2.079	2.088	2.097	2.106	2.115	2.124	2.133	2.142	2.151	2.160	2.169	2.178	2.187	2.195	2.204
173.	2.087	2.097	2.106	2.115	2.124	2.133	2.142	2.151	2.160	2.169	2.178	2.187	2.196	2.205	2.214
174.	2.096	2.106	2.115	2.124	2.133	2.142	2.151	2.160	2.169	2.178	2.187	2.196	2.205	2.214	2.223
175.	2.105	2.114	2.124	2.133	2.142	2.151	2.160	2.169	2.178	2.187	2.196	2.205	2.214	2.223	2.232
176.	2.113	2.123	2.133	2.142	2.151	2.160	2.169	2.178	2.187	2.196	2.205	2.214	2.223	2.232	2.241
177.	2.122	2.132	2.142	2.151	2.160	2.169	2.178	2.187	2.196	2.205	2.215	2.224	2.233	2.241	2.250
178.	2.131	2.141	2.151	2.160	2.169	2.178	2.187	2.197	2.206	2.215	2.224	2.233	2.242	2.251	2.260
179.	2.140	2.150	2.159	2.169	2.178	2.187	2.196	2.206	2.215	2.224	2.233	2.242	2.251	2.260	2.269
180.	2.148	2.158	2.167	2.177	2.186	2.195	2.205	2.214	2.223	2.232	2.242	2.251	2.260	2.269	2.277
181.	2.157	2.167	2.176	2.186	2.195	2.204	2.214	2.223	2.232	2.241	2.251	2.260	2.269	2.278	2.287
182.	2.166	2.176	2.185	2.195	2.204	2.213	2.223	2.232	2.241	2.250	2.260	2.269	2.278	2.287	2.296
183.	2.174	2.184	2.193	2.203	2.212	2.222	2.231	2.241	2.250	2.259	2.269	2.278	2.287	2.296	2.305
184.	2.183	2.193	2.202	2.212	2.221	2.231	2.240	2.250	2.259	2.268	2.278	2.287	2.296	2.305	2.314
185.	2.191	2.201	2.211	2.221	2.230	2.240	2.249	2.259	2.268	2.277	2.287	2.296	2.305	2.314	2.323
186.	2.200	2.210	2.220	2.229	2.239	2.249	2.258	2.268	2.277	2.286	2.296	2.305	2.314	2.323	2.332
187.	2.208	2.218	2.228	2.238	2.247	2.257	2.267	2.277	2.286	2.295	2.305	2.314	2.323	2.332	2.341
188.	2.217	2.227	2.237	2.247	2.256	2.266	2.276	2.286	2.295	2.304	2.314	2.323	2.332	2.341	2.351
189.	2.226	2.236	2.246	2.256	2.265	2.275	2.285	2.295	2.304	2.313	2.323	2.332	2.341	2.350	2.360
190.	2.234	2.244	2.254	2.264	2.274	2.283	2.293	2.303	2.312	2.322	2.331	2.341	2.350	2.359	2.369
191.	2.242	2.253	2.263	2.272	2.282	2.292	2.302	2.312	2.321	2.330	2.340	2.350	2.359	2.368	2.378
192.	2.251	2.261	2.271	2.281	2.291	2.301	2.311	2.321	2.330	2.339	2.349	2.359	2.368	2.377	2.387
193.	2.260	2.270	2.280	2.290	2.300	2.310	2.320	2.330	2.339	2.348	2.358	2.368	2.377	2.386	2.396
194.	2.268	2.279	2.289	2.299	2.308	2.318	2.328	2.338	2.347	2.357	2.367	2.377	2.386	2.396	2.405
195.	2.277	2.287	2.297	2.307	2.317	2.327	2.337	2.347	2.356	2.366	2.376	2.386	2.395	2.404	2.414
196.	2.285	2.296	2.306	2.316	2.326	2.336	2.346	2.356	2.365	2.375	2.385	2.394	2.404	2.413	2.423
197.	2.294	2.304	2.314	2.324	2.334	2.344	2.354	2.364	2.374	2.383	2.393	2.403	2.413	2.422	2.432
198.	2.302	2.313	2.323	2.333	2.343	2.353	2.363	2.373	2.382	2.392	2.402	2.412	2.422	2.431	2.441
199.	2.310	2.321	2.331	2.341	2.351	2.361	2.371	2.381	2.391	2.401	2.411	2.421	2.431	2.440	2.450

TABLE 300  
CALORIES PER SQUARE METER OF BODY SURFACE PER HOUR  
(HEIGHT-WEIGHT FORMULA)  
(Aub and DuBois, 1916)<sup>1</sup>

Age (Years)	Males	Females
14-16	46.0	43.0
16-18	43.0	40.0
18-20	41.0	38.0
20-30	39.5	37.0
30-40	39.5	36.5
40-50	38.5	36.0
50-60	37.5	35.0
60-70	36.5	34.0
70-80	35.5	33.0

TABLE 301  
STANDARD VALUES FOR CALORIES PER SQUARE METER PER HOUR  
(Boothby, Berkson and Dunn, 1936)<sup>4</sup>

Males		Females	
Age Last Birthday (Years)	Mean	Age Last Birthday (Years)	Mean
6	53.00	6	50.62
7	52.45	6½	50.23
8	51.78	7	49.12
8½	51.20	7½	47.84
9	50.54	8	47.00
9½	49.42	8½	46.50
10	48.50	9-10	45.90
10½	47.71	11	45.26
11	47.18	11½	44.80
12	46.75	12	44.28
13-15	46.35	12½	43.58
16	45.72	13	42.90
16½	45.30	13½	42.10
17	44.80	14	41.45
17½	44.03	14½	40.74
18	43.25	15	40.10
18½	42.70	15½	39.40
19	42.32	16	38.85
19½	42.00	16½	38.30
20-21	41.43	17	37.82
22-23	40.82	17½	37.40
24-27	40.24	18-19	36.74
28-29	39.81	20-24	36.18
30-34	39.34	25-44	35.70
35-39	38.68	45-49	34.94
40-44	38.00	40-54	33.96
45-49	37.37	55-59	33.18
50-54	36.73	60-64	32.61
55-59	36.10	65-69	32.30
60-64	35.48		
65-69	34.80*		

\* Obtained by extrapolation.

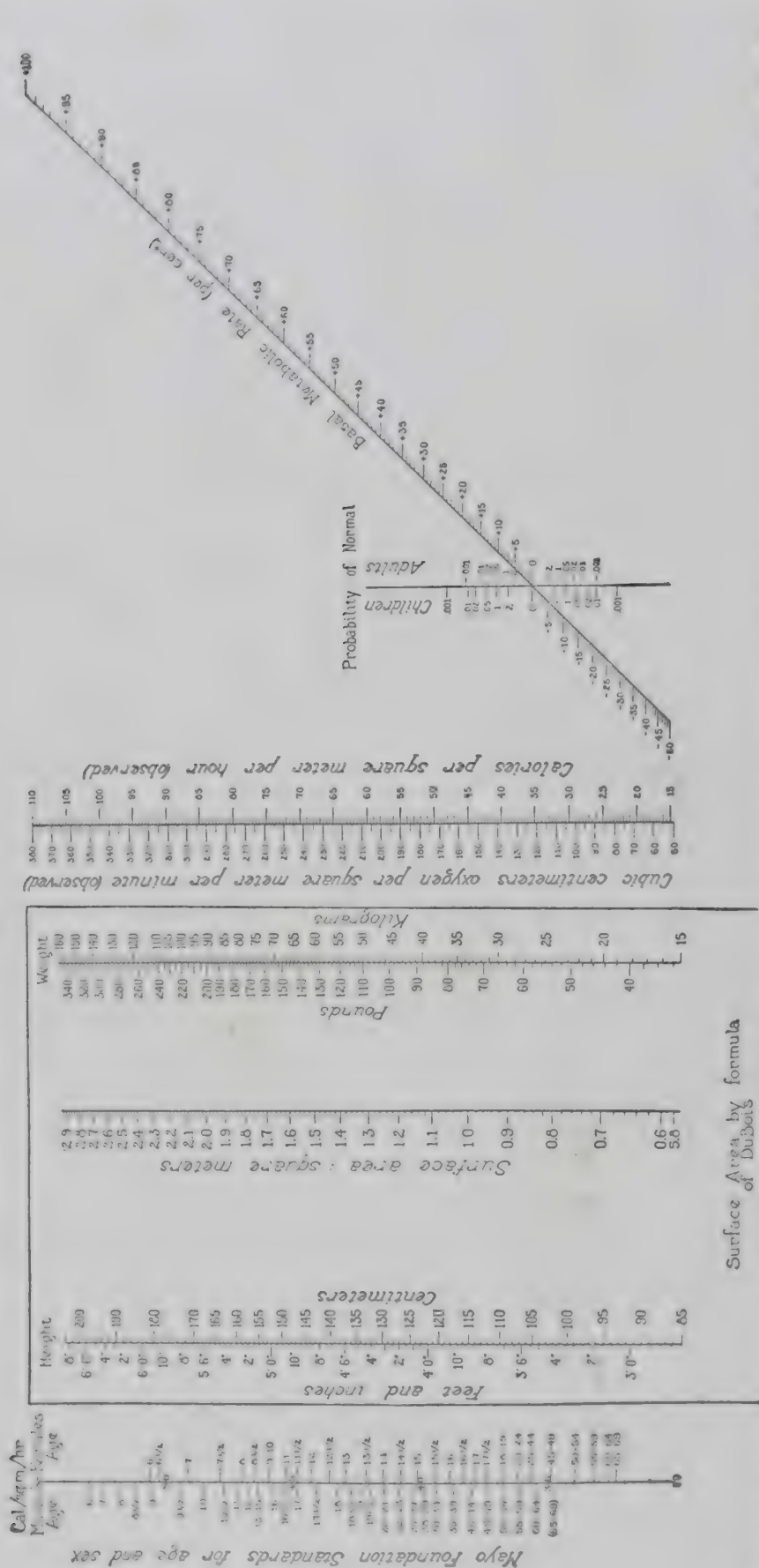


Fig. 209. Nomogram for use in computing the basal metabolic rate and determining the probability of normality. (Boothby, W. M., Berkson, J., and Dunn, H. L.: *Am. J. Physiol.*, vol. 116.)

To determine the basal metabolic rate, place a pin or needle on the observed calories per square meter (DuBois) or cubic centimeters of oxygen per square meter (DuBois) and swing the left hand end of the ruler to the age of the subject for the appropriate sex on the left hand upright line. The Mayo Foundation standards for age and sex. Read the basal metabolic rate in per cent on the right hand oblique line where the ruler crosses that line. In using the age standard, express age as of the last birthday; observe half years when these are given on the nomogram. To determine the "probability of normal," read, before removing the ruler, the decimal on the short upright line. If it reads 0.02, that means that out of every 100 normal people two can be expected to have a basal metabolic rate as great (smaller) as or greater (smaller) than that observed in this particular subject. For this nomogram, "adult" refers to persons 20 years of age or more.

For example, a boy 9 years old whose observed metabolism is 55.5 calories per square meter per hour, has a basal metabolic rate of plus 10 per cent, and five out of 100 normal boys of his age can be expected to have a basal metabolic rate of plus 10 per cent or

NORMAL STANDARDS. Normal standards for basal metabolism used in this country are usually those of Aub and DuBois<sup>1</sup> (Table 300) or of Boothby, Berkson and Dunn<sup>2</sup> (Table 301), both of which are based on measurements of

TABLE 302  
NORMAL STANDARDS\*  
*Harris-Benedict Standards Based on Body Weight*  
(Roth, 1924)<sup>13</sup>

Weight, Kg.	Cal. per Hour		Weight, Kg.	Cal. per Hour	
	Males	Females		Males	Females
10.....	8.5	.....	72.....	44.0	56.0
12.....	9.7	.....	74.....	45.2	56.8
14.....	10.8	.....	76.....	46.3	57.6
16.....	12.0	.....	78.....	47.5	58.4
18.....	13.1	.....	80.....	48.6	59.2
20.....	14.3	.....	82.....	49.7	60.0
22.....	15.4	.....	84.....	50.9	60.8
24.....	16.6	.....	86.....	52.0	61.6
26.....	17.7	37.6	88.....	53.2	62.4
28.....	18.8	38.4	90.....	53.3	63.2
30.....	19.9	39.2	92.....	55.5	64.0
32.....	21.1	40.0	94.....	56.6	64.8
34.....	22.2	40.8	96.....	57.8	65.6
36.....	23.4	41.6	98.....	58.9	66.4
38.....	24.5	42.4	100.....	60.1	67.2
40.....	25.7	43.2	102.....	61.2	68.0
42.....	26.8	44.0	104.....	62.4	68.8
44.....	28.0	44.8	106.....	63.5	69.6
46.....	29.1	45.6	108.....	64.7	70.4
48.....	30.3	46.4	110.....	65.8	71.2
50.....	31.4	47.2	112.....	67.0	72.0
52.....	32.6	48.0	114.....	68.1	72.8
54.....	33.7	48.8	116.....	69.3	73.6
56.....	34.9	49.6	118.....	70.4	74.4
58.....	36.0	50.4	120.....	71.6	75.2
60.....	37.2	51.2	122.....	72.7	76.0
62.....	38.3	52.0	124.....	73.9	76.8
64.....	39.5	52.8	126.....	75.0	77.6
66.....	40.6	53.6	128.....	76.1	78.4
68.....	41.8	54.4	130.....	77.2	79.2
70.....	42.9	55.2			

\* The predicted calories per hour are obtained by adding the calories corresponding to the weight in kilograms (A) to the calories corresponding to age and stature (B, C, D). In the use of these condensed tables, interpolation is necessary.

surface area. The prediction tables of Harris and Benedict<sup>7</sup> (Table 302), based on biometric studies, are also used and are derived from the following equations:

Men:  $H = 66.473 + 13.751W + 5.0033S - 6.7550A$   
Women:  $H = 655.0955 + 9.5634W + 1.8496S - 4.6756A$

where *H* is total heat production in calories per twenty-four hours, *W* weight in kilograms, *S* height in centimeters, and *A* age in years.

The Boothby, Berkson and Dunn<sup>4</sup> standards cover a range of ages from six to sixty-eight years and differ slightly from those of Aub and DuBois.

The standards based on the Harris and Benedict equations and calculated by Roth<sup>13</sup> are given in Table 303.

The values for normal standards are the averages for groups within the same age limits, the same sex and surface area, or height or weight, depending upon which measurement is employed. The normal range usually is assumed to be between plus or minus 10 per cent and plus or minus 15 per cent of the standard values. A few individuals will deviate further and still be normal.

TABLE 303  
HARRIS-BENEDICT STANDARDS BASED ON AGE AND STATURE  
(Roth, 1924)<sup>13</sup>

Men											
Cm.	Age 20	Age 25	Age 30	Age 35	Age 40	Age 45	Age 50	Age 55	Age 60	Age 65	Age 70
150.....	25.6	24.2	22.8	21.4	20.0	18.6	17.2	15.8	14.4	13.0	11.6
155.....	26.6	25.2	23.8	22.4	21.0	19.6	18.2	16.8	15.4	14.0	12.6
160.....	27.7	26.3	24.9	23.5	22.1	20.7	19.3	17.9	16.5	15.1	13.7
165.....	28.7	27.3	25.9	24.5	23.1	21.7	20.3	18.9	17.5	16.1	14.1
170.....	29.8	28.4	27.0	25.6	24.2	22.8	21.4	20.0	18.6	17.2	15.8
175.....	30.8	29.4	28.0	26.6	25.2	23.8	22.4	21.0	19.6	18.2	16.8
180.....	31.9	30.4	29.1	27.6	26.2	24.8	23.4	22.0	20.6	19.2	17.8
185.....	32.9	31.5	30.1	28.7	27.3	25.9	24.5	23.1	21.7	20.3	18.9
190.....	34.0	32.5	31.2	29.7	28.3	26.9	25.5	24.1	22.7	21.3	19.9
195.....	35.0	33.6	32.2	30.8	29.4	28.0	26.6	25.2	23.8	22.4	21.0
200.....	36.1	34.6	33.2	31.8	30.4	29.0	27.6	26.2	24.8	23.4	22.0

Women											
150.....	7.7	6.7	5.7	4.7	3.8	2.8	1.8	0.9	0.0	-1.0	-2.0
155.....	8.1	7.1	6.1	5.1	4.2	3.2	2.2	1.2	0.2	-0.7	-1.7
160.....	8.5	7.5	6.5	5.5	4.5	3.6	2.6	1.6	0.6	-0.3	-1.3
165.....	8.8	7.8	6.9	5.9	4.9	4.0	3.0	2.0	1.0	0.0	-0.9
170.....	9.2	8.2	7.3	6.3	5.3	4.3	3.4	2.4	1.4	0.5	-0.5
175.....	9.6	8.6	7.6	6.7	5.7	4.7	3.7	2.8	1.8	0.8	-0.2
180.....	10.0	9.0	8.0	7.0	6.1	5.1	4.1	3.2	2.2	1.2	0.2
185.....	10.4	9.4	8.4	7.5	6.5	5.5	4.5	3.5	2.6	1.6	0.6
190.....	10.8	9.8	8.8	7.8	6.8	5.9	4.9	3.9	3.0	2.0	1.0
195.....	11.2	10.2	9.2	8.2	7.2	6.2	5.3	4.3	3.3	2.4	1.4
200.....	11.5	10.5	9.6	8.6	7.6	6.7	5.7	4.7	3.7	2.7	1.8

Boothby, Berkson and Dunn<sup>4</sup> determined the probability of normality statistically as shown in the nomogram (Fig. 209).

NORMAL STANDARDS FOR CHILDREN IN RELATION TO AGE, WEIGHT, HEIGHT AND SURFACE AREA. Since the body surface standards for adults have been found unsatisfactory when applied to children, Talbot's<sup>18</sup> standards for children are given in Tables 304 and 305.

Lewis, Kinsman and Iliff,<sup>9</sup> in their study of boys and girls from two to twelve years of age, inclusive, devised the standard (Tables 306, 307, 308 and 309) expressed as calories per square meter of body surface per hour in relation to age; calories per hour per kilogram of body weight; calories per hour per centimeter of height; and calories per hour per square meter of surface area.

The mean coefficients of variation for Tables 306, 307 and 308 show that theoretically 99.7 per cent of all tests fall within plus or minus 18 per cent of means for boys and within plus or minus 16 per cent for girls, and that 95 per cent fall within plus or minus 12 per cent for boys and plus or minus 11 per cent for girls. These three tables are presented as prediction standards.

TABLE 304  
STANDARD TOTAL CALORIES FOR WEIGHT  
(Talbot, 1938)<sup>18</sup>

<i>Weight in Kg.</i>	<i>Total Calories per 24 Hours</i>		<i>Weight in Kg.</i>	<i>Total Calories per 24 Hours</i>	
	Girls	Boys		Girls	Boys
3.0.....	136	150	36.0.....	1173	1270
4.0.....	205	210	38.0.....	1207	1305
5.0.....	274	270	40.0.....	1241	1340
6.0.....	336	330	42.0.....	1274	1370
7.0.....	395	390	44.0.....	1306	1400
8.0.....	448	445	46.0.....	1338	1430
9.0.....	496	495	48.0.....	1369	1460
10.0.....	541	545	50.0.....	1399	1485
11.0.....	582	590	52.0.....	1429	1505
12.0.....	620	625	54.0.....	1458	1555
13.0.....	655	665	56.0.....	1487	1580
14.0.....	687	700	58.0.....	1516	1600
15.0.....	718	725	60.0.....	1544	1630
16.0.....	747	750	62.0.....	1572	1660
17.0.....	775	780	64.0.....	1599	1690
18.0.....	802	810	66.0.....	1626	1725
19.0.....	827	840	68.0.....	1653	1765
20.0.....	852	870	70.0.....	1679	1785
22.0.....	898	910	72.0.....	1705	1815
24.0.....	942	980	74.0.....	1731	1845
26.0.....	984	1070	76.0.....	1756	1870
28.0.....	1025	1100	78.0.....	1781	1900
30.0.....	1063	1140	80.0.....	1805	.....
32.0.....	1101	1190	82.0.....	1830	.....
34.0.....	1137	1230	84.0.....	1855	2000

Shock<sup>16</sup> determined the basal metabolism of fifty boys and fifty girls between the ages of eleven and one-half and eighteen years on two successive days every six months. Table 310 gives the mean values for various ages.

In 95 per cent of normal children the basal metabolic rate is within plus or minus 15 per cent of the standard values.

Normal physiologic conditions influence the basal metabolic rate, the more important of which are menstruation and pregnancy.

IN RELATION TO MENSTRUATION. During the normal menstrual cycle the

basal metabolic rate may change, being highest in the premenstrual period and lowest during menstruation and the intermenstrual period.

In addition to showing the scattering, Wakeham<sup>24</sup> plotted the curve of the average basal metabolic rate in relation to menstruation (Fig. 210). The dotted line is the mean of three determinations made on the first day of menstruation.

Blunt and Dye<sup>3</sup> found that the average metabolism during menstruation was 1.6 per cent lower than during the other days of the cycle.

TABLE 305  
STANDARD TOTAL CALORIES FOR HEIGHT  
(Total Calories for the Expected Weight)  
(Talbot, 1938)<sup>18</sup>

Height in Cm.	Total Calories per 24 Hours		Height in Cm.	Total Calories per 24 Hours	
	Girls	Boys		Girls	Boys
48.....	134	...	92.....	681	725
50.....	159	...	94.....	695	740
51.....	...	160	96.....	709	755
52.....	186	175	98.....	722	765
54.....	214	200	100.....	735	785
56.....	246	225	105.....	770	805
58.....	278	260	110.....	807	830
60.....	309	300	115.....	846	875
62.....	341	315	120.....	894	935
64.....	373	360	125.....	942	990
66.....	404	390	130.....	987	1045
68.....	433	420	135.....	1057	1105
70.....	462	450	140.....	1130	1165
72.....	489	480	145.....	1208	1220
74.....	515	510	150.....	1294	1290
76.....	539	535	155.....	1386	1380
78.....	560	565	160.....	1477	1480
80.....	581	590	165.....	1544	1570
82.....	601	612	170.....	1584	1655
84.....	619	635	175.....	1596	1720
86.....	636	660	180.....	1600	1800
88.....	652	685	190.....	....	1900
90.....	666	705			

IN RELATION TO PREGNANCY. Carpenter and Murlin,<sup>5</sup> in a study of three pregnant women, concluded that energy metabolism in the latter part of pregnancy is about 4 per cent higher than that of women at complete sexual rest. After delivery they found an increased metabolism, ascribed in part to the activity of the mammary glands and in part to the dynamic action of protein during the involution process.

One of the outstanding studies during pregnancy is that of Root and Root.<sup>25</sup> They found the basal metabolism during the fourth month of pregnancy to be

4 per cent below the Harris and Benedict<sup>7</sup> prediction standards. The rate gradually increased until the eleventh day before delivery, when it was 12.1 per cent above the Harris and Benedict standards. The rate remained stationary for a few days after delivery and then gradually decreased for about six weeks until it was 12.9 per cent below the Harris and Benedict standards.

Rowe, Alcott and Mortimer<sup>14</sup> studied forty-six cases of pregnancy and found the averages to be from minus 8 per cent early in pregnancy to plus 7 per cent

TABLE 306

CENTRAL TREND LINE VALUES FOR CALORIES PER HOUR PER SQUARE METER OF BODY SURFACE (DuBois and DuBois Height-Weight Formula, with constant 71.84 IN RELATION TO AGE

(Lewis, Kinsman and Iliff, 1937)<sup>9</sup>

Age, Years	Calories per Hour per Sq. M.		Age, Years	Calories per Hour per Sq. M.	
	Boys	Girls		Boys	Girls
00.....	54.3	52.6	7.75.....	47.4	44.7
25.....	54.0	52.3	8.00.....	47.1	44.3
50.....	53.7	51.9	8.25.....	46.8	44.0
75.....	53.4	51.6	8.50.....	46.5	43.7
00.....	53.1	51.2	8.75.....	46.2	43.4
25.....	52.8	50.9	9.00.....	45.9	43.0
50.....	52.5	50.5	9.25.....	45.6	42.7
75.....	52.2	50.2	9.50.....	45.3	42.3
00.....	51.9	49.8	9.75.....	45.0	42.0
25.....	51.6	49.5	10.00.....	44.7	41.6
50.....	51.3	49.2	10.25.....	44.4	41.3
75.....	51.0	48.9	10.50.....	44.1	40.9
00.....	50.7	48.5	10.75.....	43.8	40.6
25.....	50.4	48.2	11.00.....	43.5	40.2
50.....	50.1	47.8	11.25.....	43.2	39.9
75.....	49.8	47.5	11.50.....	42.9	39.5
00.....	49.5	47.1	11.75.....	42.6	39.2
25.....	49.2	46.8	12.00.....	42.3	38.8
50.....	48.9	46.4	12.25.....	42.0	38.5
75.....	48.6	46.1	12.50.....	41.7	38.1
00.....	48.3	45.7	12.75.....	41.4	37.8
25.....	48.0	45.4	13.00.....	41.1	37.4
50.....	47.7	45.0			

just before delivery. After delivery there was a drop of 10 per cent below normal with a gradual rise during the next few weeks.

Sandiford and Wheeler<sup>15</sup> studied the basal metabolism of a woman before pregnancy, during pregnancy, puerperium and for four months after cessation of lactation and the reestablishment of menstruation, a total period of seventeen months. There was less than plus or minus 3 per cent monthly variation during the first six months. During the eighth month there was a gradual increase in

total energy production, the peak being reached in the last month. On the day of delivery the patient's weight was 23 per cent greater than before becoming pregnant, and the total heat production had increased 25 per cent. The author concluded that there was practically no change in heat production per kilogram of body weight. The increase in total heat production was due to the metabolism of new tissue, mostly that of the fetus, the remainder to maternal structure.

TABLE 307

CENTRAL TREND LINE VALUES FOR CALORIES PER HOUR IN RELATION TO WEIGHT  
(Lewis, Kinsman and Iliff,1937)<sup>9</sup>

Weight in Kg.	Calories per Hour		Weight in Kg.	Calories per Hour	
	Boys	Girls		Boys	Girls
12.0	29.7	28.0	24.5	44.6	42.6
12.5	30.4	29.1	25.0	45.0	43.0
13.0	31.2	29.7	25.5	45.4	43.4
13.5	31.9	30.4	26.0	45.8	43.8
14.0	32.5	31.0	26.5	46.2	44.3
14.5	33.2	31.6	27.0	46.6	44.7
15.0	33.9	32.2	27.5	47.0	45.1
15.5	34.6	32.9	28.0	47.3	45.5
16.0	35.2	33.5	28.5	47.6	46.0
16.5	35.8	34.1	29.0	47.9	46.4
17.0	36.5	34.7	29.5	48.2	46.7
17.5	37.1	35.4	30.0	48.5	47.0
18.0	37.7	36.0	30.5	48.8	
18.5	38.3	36.6	31.0	49.1	
19.0	38.8	37.2	31.5	49.4	
19.5	39.4	37.8	32.0	49.7	
20.0	40.0	38.4	32.5	49.9	
20.5	40.6	39.0	33.0	50.2	
21.0	41.2	39.5	33.5	50.5	
21.5	41.8	40.0	34.0	50.7	
22.0	42.3	40.4	34.5	50.9	
22.5	42.8	40.9	35.0	51.1	
23.0	43.3	41.3	35.5	51.3	
23.5	43.7	41.8	36.0	51.5	
24.0	44.1	42.2			

There was no significant change in heat production during lactation. As conditions became normal and the mother resumed her usual activities, the total heat production became practically that noted before pregnancy.  
Figure 211 shows the findings for the entire period of study.

TABLE 308  
CENTRAL TREND LINE VALUES FOR CALORIES PER HOUR IN RELATION TO HEIGHT  
(Lewis, Kinsman and Iliff, 1937)<sup>a</sup>

Height in Cm.	Calories per Hour		Height in Cm.	Calories per Hour	
	Boys	Girls		Boys	Girls
84		26.4	118	41.1	39.3
86		27.1	120	41.8	40.1
88	29.8	27.9	122	42.6	40.8
90	30.5	28.6	124	43.3	41.6
92	31.2	29.4	126	44.1	42.3
94	32.0	30.1	128	44.8	43.1
96	32.7	30.9	130	45.6	43.8
98	33.5	31.7	132	46.3	44.6
100	34.2	32.4	134	47.1	45.3
102	35.0	33.2	136	47.8	46.1
104	35.8	34.0	138	48.6	46.9
106	36.5	34.7	140	49.4	47.6
108	37.3	35.5	142	50.1	48.4
110	38.0	36.3	144	50.8	49.2
112	38.8	37.0	146	51.6	49.9
114	39.6	37.8	148	52.4	
116	40.3	38.6	150	53.2	

TABLE 309  
CENTRAL TREND LINE VALUES FOR CALORIES PER HOUR IN RELATION TO BODY SURFACE  
(DuBois and DuBois Height-Weight Formula, with Constant 71.84)  
(Lewis, Kinsman and Iliff, 1937)<sup>a</sup>

Body Surface, Sq. M.	Calories per Hour		Body Surface, Sq. M.	Calories per Hour	
	Boys	Girls		Boys	Girls
0.540	29.9	28.4	0.940	44.8	43.0
0.560	30.8	29.3	0.960	45.4	43.7
0.580	31.6	30.1	0.980	46.0	44.3
0.600	32.5	30.9	1.000	46.6	44.9
0.620	33.4	31.7	1.020	47.1	45.4
0.640	34.2	32.5	1.040	47.7	45.9
0.660	35.0	33.2	1.060	48.2	46.4
0.680	35.8	33.9	1.080	48.8	46.9
0.700	36.5	34.6	1.100	49.3	47.4
0.720	37.2	35.3	1.120	49.8	47.8
0.740	37.9	36.0	1.140	50.2	48.2
0.760	38.6	36.7	1.160	50.6	48.7
0.780	39.3	37.4	1.180	51.0	49.1
0.800	40.0	38.1	1.200	51.5	49.5
0.820	40.7	38.8	1.220	51.9	
0.840	41.4	39.5	1.240	52.3	
0.860	42.1	40.2	1.260	52.6	
0.880	42.8	40.9	1.280	53.0	
0.900	43.5	41.6	1.300	53.2	
0.920	44.2	42.3			

TABLE 310  
MEAN VALUES OF BASAL OR STANDARD METABOLISM  
(AN APPLICATION OF THE DUBOIS STANDARDS TO THE ADOLESCENT PERIOD OF LIFE  
(Shock, 1942)<sup>16</sup>

Age in Years	Calories per Square Meter per Hour		Age in Years	Calories per Square Meter per Hour	
	Male	Female		Male	Female
11.5.....	43.6	41.7	15.0.....	42.8	35.7
12.0.....	45.0	41.0	15.5.....	41.4	34.4
12.5.....	44.4	40.4	16.0.....	41.1	34.2
13.0.....	44.1	39.9	16.5.....	41.0	34.6
13.5.....	43.2	38.8	17.0.....	40.9	33.4
14.0.....	43.5	38.0	17.5.....	40.6	33.4
14.5.....	42.9	36.5			

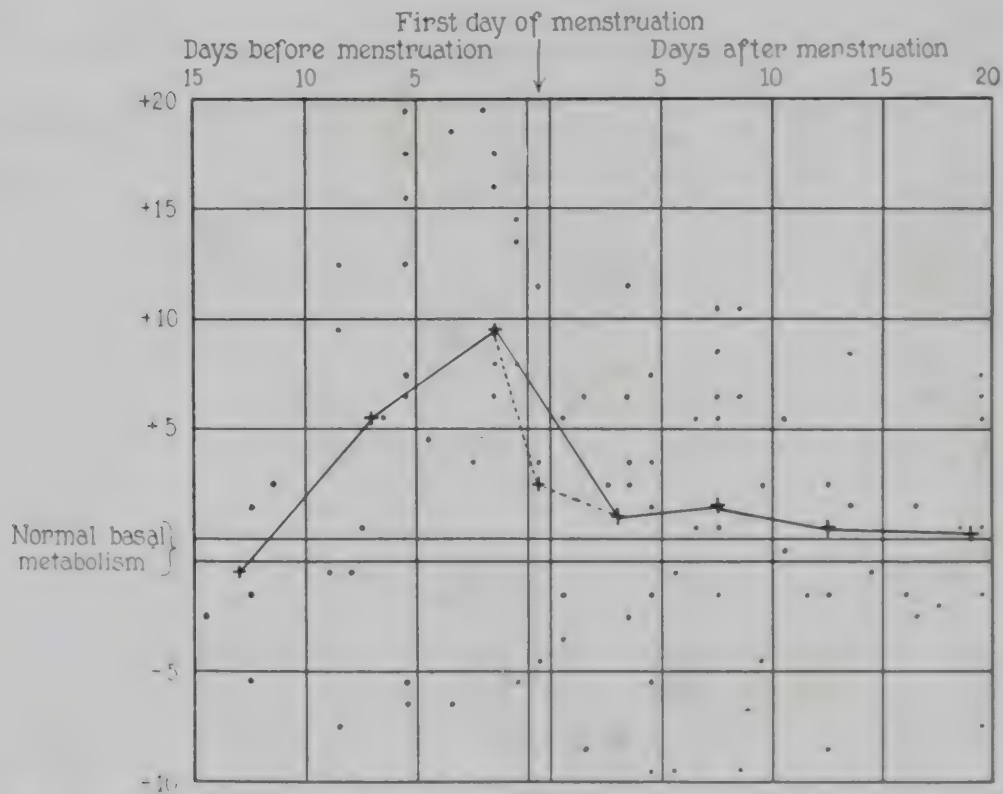


Fig. 210. Basal metabolic rate in relation to menstruation (Wakeham, 1923)

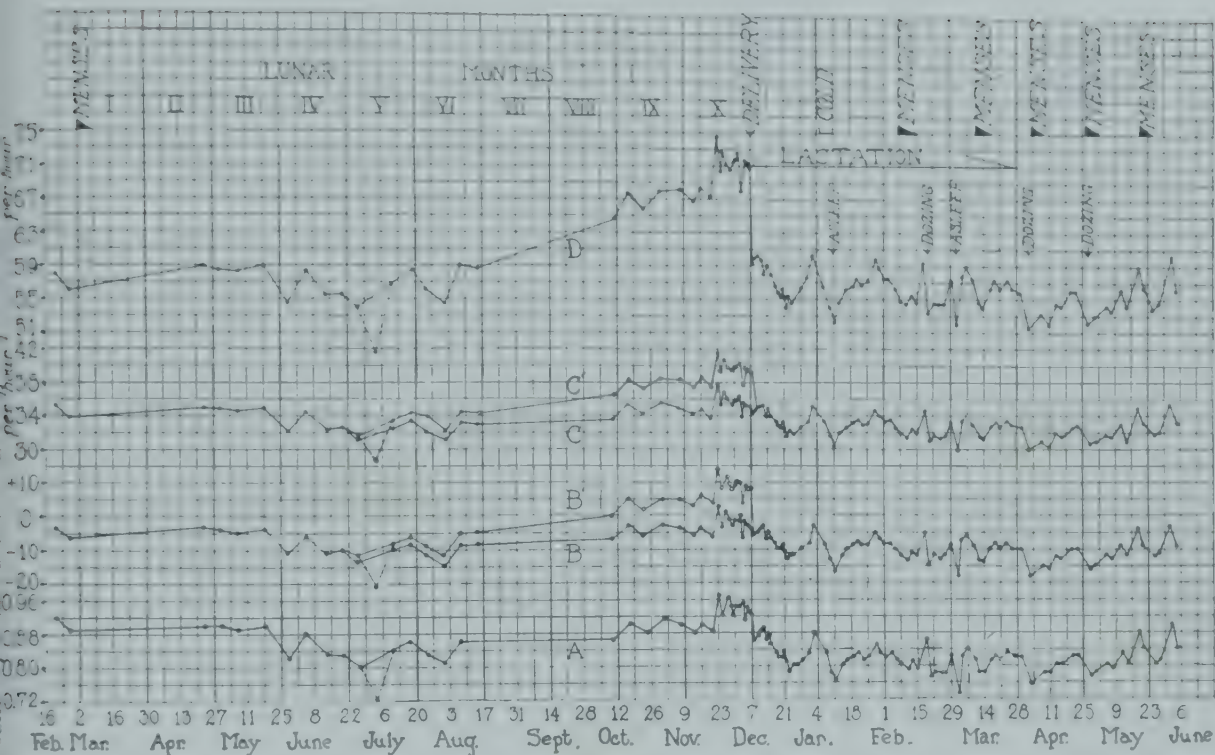


Fig. 211. Basal metabolism findings before, during, and after pregnancy. The subject, a woman aged 34 years, height 160 cm. Curve A represents the calories for each kilo; Curve B, the basal metabolic rate calculated during the course of pregnancy, by dividing the total calories each hour by the sum of the surface area of the mother and fetus, and comparing the result obtained with the DuBois normal of the mother, 36.5 calories. Curve B' represents the basal metabolic rate calculated in the usual method, using the DuBois surface area and normal standards. Curve C is the calories for each square meter each hour derived for the course of pregnancy as just described for Curve B. Curve C' represents the calories for each square meter each hour, obtained by dividing the total calories each hour by the DuBois surface area, obtained by using the total weight of mother and fetus in the usual manner. Curve D represents the total calories for each hour. (Sandiford, I., and Wheeler, T.: J. Biol. Chem., vol. 62.

TABLE 311  
CALORIC VALUE OF FOODSTUFFS\*  
OXYGEN ABSORBED AND CARBON DIOXIDE FORMED IN METABOLISM

One Gram of Substance	O <sub>2</sub> Absorbed	CO <sub>2</sub> Formed	R. Q.	Calories			
				Rubner	Loewy	O <sub>2</sub>	CO <sub>2</sub>
	Cc.	Cc.				1 liter	1 liter
Protein.....	966.3	773.9	0.801	4.10	4.316	4.485	5.579
Primary nitrogen	5939.0	4757.0	0.801	25.63	26.54	4.485	5.579
Fat.....	2019.3	1427.3	0.707	9.3	9.461	4.686	6.629
Starch.....	828.8	828.8	1.000	4.1	4.182	5.047	5.047

\* The caloric values of food are those of Rubner and Loewy, as given by Peters and Van Slyke.<sup>12</sup>

TABLE 312  
ANALYSIS OF THE OXIDATION OF MIXTURE OF CARBOHYDRATE AND FAT\*

Respiratory Quotient	Percentage of Total Oxygen Consumed by		Percentage of Total Heat Produced by		Calories per Liter (1)	
	Carbohy- drate (1)	Fat (2)	Carbohy- drate (3)	Fat (4)	Number (5)	Logarithm (6)
0.707	0	100.0	0	100.0	4.686	0.67080
0.71	1.02	99.0	1.10	98.9	4.690	0.67114
0.72	4.44	95.6	4.76	95.2	4.702	0.67228
0.73	7.85	92.2	8.40	91.6	4.714	0.67342
0.74	11.3	88.7	12.0	88.0	4.727	0.67456
0.75	14.7	85.3	15.6	84.4	4.739	0.67569
0.76	18.1	81.9	19.2	80.8	4.751	0.67682
0.77	21.5	78.5	22.8	77.2	4.764	0.67794
0.78	24.9	75.1	26.3	73.7	4.776	0.67906
0.79	28.3	71.7	29.9	70.1	4.788	0.68018
0.80	31.7	68.3	33.4	66.6	4.801	0.68129
0.81	35.2	64.8	36.9	63.1	4.813	0.68241
0.82	38.6	61.4	40.3	59.7	4.825	0.68352
0.83	42.0	58.0	43.8	56.2	4.838	0.68463
0.84	45.4	54.6	47.2	52.8	4.850	0.68573
0.85	48.8	51.2	50.7	49.3	4.862	0.68683
0.86	52.2	47.8	54.1	45.9	4.875	0.68793
0.87	55.6	44.4	57.5	42.5	4.887	0.68903
0.88	59.0	41.0	60.8	39.2	4.899	0.69012
0.89	62.5	37.5	64.2	35.8	4.911	0.69121
0.90	65.9	34.1	67.5	32.5	4.924	0.69230
0.91	69.3	30.7	70.8	29.2	4.936	0.69339
0.92	72.7	27.3	74.1	25.9	4.948	0.69447
0.93	76.1	23.9	77.4	22.6	4.961	0.69555
0.94	79.5	20.5	80.7	19.3	4.973	0.69663
0.95	82.9	17.1	84.0	16.0	4.985	0.69770
0.96	86.3	13.7	87.2	12.8	4.998	0.69877
0.97	89.8	10.2	90.4	9.58	5.010	0.69984
0.98	93.2	6.83	93.6	6.37	5.022	0.70091
0.99	96.6	3.41	96.8	3.18	5.035	0.70197
1.00	100.0	0	100.0	0	5.047	0.70303

Formula for Column

(1) Percentage =  $100 \frac{R - 0.707}{0.293}$

(2) Percentage =  $100 \frac{1.00 - R}{0.293}$

(3) Percentage =  $\frac{504.7 (R - 0.707)}{5.047 (R - 0.707) + 4.686 (1.00 - R)}$

(4) Percentage =  $\frac{468.6 (1.00 - R)}{5.047 (R - 0.707) + 4.686 (1.00 - R)}$

(5) Calories =  $4.686 + \frac{R - 0.707}{0.293} \times 0.361$

(6) Logarithm = log of column 5

\* The data are those of Zuntz and Schumburg, as modified by Lusk. <sup>10</sup>

TABLE 313

ENERGY REQUIREMENTS OF PERSONS OF THE SAME SIZE ENGAGED IN DIFFERENT TYPES OF ACTIVITY

(Turner, 1939)<sup>19</sup>

Type of Exercise	Calories per Pound of Body Weight per Day	Calories per Kilo of Body Weight per Day	Total Calories per Day for a Man Weighing 155 Pounds (70 Kg.)
<i>Light Exercise</i> (Seamstress, typist, tailor) . . . . .	13-16	30-35	2100-2450
<i>Moderate Exercise</i> (Metal worker, furniture painter) . . . . .	18-20	40-45	2800-3150
<i>Severe Exercise</i> (Stone mason, laborer, mason) . . . . .	22-32	50-70	3500-4900

TABLE 314

STRENGTH OF WOMEN COMPARED WITH THAT OF MEN

(Jetyko, 1934)<sup>8</sup>

Test of Strength	Ratio Strength Index $\frac{\text{Women}}{\text{Men}}$
Dynamometer . . . . .	570/1000
Ergograph . . . . .	679/1000

TABLE 315

STRENGTH IN RELATION TO WEIGHT

(Martin, 1921)<sup>11</sup>

	Average Strength Kg.	Strength/Weight Ratio
College women . . . . .	1360	22.5
Industrial women . . . . .	910	15.5
College men . . . . .	1800	26.6
Industrial men . . . . .	1965	25.2

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## Chapter 62

# NORMAL STANDARDS FOR GROWTH, HEIGHT AND WEIGHT

### STANDARDS FOR CHILDREN

THE DETERMINATION of normal standards for height, weight and growth in infants and children is complicated by racial and geographical factors, and by variations in skeletal proportion and structure. A number of complicated methods have been devised for determining normal standards of nutritional status in children, some of which involve elaborate measurements of various lengths, circumferences and diameters. Such methods are impractical for ordinary clinical use or for application to large groups of persons. Likewise, such data lead to inaccuracy when used as the basis for calculation of the basal metabolic rate in children who are definitely outside the normal range in either height or weight.



Fig. 212. Growth charts. Solid lines indicate average normals; broken lines, 10 per cent above or below ideal normals. (Barach, J. H.: *Diabetes and Its Treatment*, Oxford University Press.)

Among the numerous charts and tables which have appeared, lack of agreement is striking.<sup>6</sup> The charts prepared by Barach seem to be satisfactorily representative. From various investigators' measurements of over 400,000 children Barach determined the mean values of height and weight at each age for each study and from these averaged means calculated his growth charts.

TABLE 316  
NORMAL HEIGHT-WEIGHT  
(Barach, 1945)<sup>2</sup>

<i>Age in Years</i>	<i>Male</i>		<i>Female</i>	
	Height in Inches	Weight in Pounds	Height in Inches	Weight in Pounds
$\frac{1}{2}$ .....	26	17	26	16
1.....	29	21	29	20
2.....	33	26	33	25
3.....	36	31	36	30
4.....	39	35	39	34
5.....	42	38	41	37
6.....	45	43	44	43
7.....	47	50	47	47
8.....	49	55	49	54
9.....	51	61	51	60
10.....	53	67	53	67
11.....	55	75	55	74
12.....	57	81	57	82
13.....	59	90	60	94
14.....	62	103	62	105
15.....	64	112	63	112
16.....	66	126	64	117
17.....	67	133	64	122
18.....	68	138	65	124
19.....	69	138	65	126
20.....	69	139	65	126

TABLE 317

HEIGHTS AND WEIGHTS OF CHILDREN BETWEEN 1 AND 4 YEARS OF AGE (WITHOUT CLOTHES)  
(F. S. Crum)\*

Age, Months	5602 Boys		4821 Girls	
	Height, Inches	Weight, Pounds	Height, Inches	Weight, Pounds
6	26.5	18.0	25.9	16.8
7	27.3	19.1	26.5	17.4
8	27.6	19.8	27.0	18.3
9	28.1	20.4	27.6	19.1
10	28.5	20.9	27.9	19.5
11	29.0	21.4	28.4	20.1
12	29.4	21.9	28.9	20.8
13	29.9	22.9	29.4	21.0
14	30.3	23.0	29.5	21.6
15	30.8	23.6	30.1	21.9
16	31.1	24.1	30.5	22.6
17	31.4	24.5	30.8	22.9
18	31.8	24.6	31.1	23.4
19	32.3	25.5	31.5	23.8
20	32.6	25.8	32.0	24.1
21	32.9	25.8	32.3	24.8
22	33.3	26.9	32.6	25.3
23	33.6	27.0	32.9	25.6
24	33.8	27.1	33.4	26.4
25	34.0	27.9	33.8	26.9
26	34.1	28.3	33.9	27.3
27	34.8	29.0	33.9	27.3
28	35.1	29.1	34.6	27.8
29	35.4	29.3	34.8	27.8
30	35.4	29.5	34.9	28.3
31	35.5	30.5	35.1	28.8
32	36.0	30.6	35.4	29.0
33	36.1	30.6	35.6	29.1
34	36.5	31.1	36.5	30.1
35	36.8	31.9	36.5	30.3
36	37.1	32.3	36.8	30.5
37	37.4	32.3	36.8	30.8
38	37.5	32.4	37.0	31.0
39	37.9	33.1	37.3	31.6
40	38.4	33.5	37.5	32.0
41	38.6	33.6	37.8	32.3
42	38.6	33.8	38.0	32.5
43	38.8	33.8	38.3	32.8
44	38.9	34.3	38.5	33.0
45	39.0	34.5	38.5	33.5
46	39.0	34.8	38.8	33.5
47	39.3	35.8	38.9	33.5
48	39.5	35.9	39.0	33.8

\* Quarterly Publication of the American Statistical Association, Boston, N.S., No. 115, 15, 332, 1916.

TABLE 318  
HEIGHT-WEIGHT-AGE TABLES  
Boys

Height, Inches	5 Yrs.	6 Yrs.	7 Yrs.	8 Yrs.	9 Yrs.	10 Yrs.	11 Yrs.	12 Yrs.	13 Yrs.	14 Yrs.	15 Yrs.	16 Yrs.	17 Yrs.	18 Yrs.	19 Yrs.
38	34	34													
39	35	35													
40	36	36													
41	38	38	38												
42	39	39	39	39											
43	41	41	41	41											
44	44	44	44	44											
45	46	46	46	46	46										
46	47	48	48	48	48										
47	49	50	50	50	50	50									
48		52	53	53	53	53									
49		55	55	55	55	55	55								
50		57	58	58	58	58	58	58							
51			61	61	61	61	61	61							
52			63	64	64	64	64	64	64						
53			66	67	67	67	67	68	68						
54				70	70	70	70	71	71	72					
55				72	72	73	73	74	74	74					
56				75	76	77	77	77	78	78	80				
57					79	80	81	81	82	83	83				
58					83	84	84	85	85	86	87				
59						87	88	89	89	90	90	90			
60						91	92	92	93	94	95	96			
61							95	96	97	99	100	103	106		
62							100	101	102	103	104	107	111	116	
63							105	106	107	108	110	113	118	123	127
64								109	111	113	115	117	121	126	130
65								114	117	118	120	122	127	131	134
66									119	122	125	128	132	136	139
67									124	128	130	134	136	139	142
68										134	134	137	141	143	147
69										137	139	143	146	149	152
70										143	144	145	148	151	155
71										148	150	151	152	154	159
72											153	155	156	158	163
73											157	160	162	164	167
74											160	164	168	170	171

TABLE 318—Continued  
HEIGHT-WEIGHT-AGE TABLES  
Girls

Height, Inches	5 Yrs.	6 Yrs.	7 Yrs.	8 Yrs.	9 Yrs.	10 Yrs.	11 Yrs.	12 Yrs.	13 Yrs.	14 Yrs.	15 Yrs.	16 Yrs.	17 Yrs.	18 Yrs.
38	33	33												
39	34	34												
40	36	36	36											
41	37	37	37											
42	39	39	39											
43	41	41	41	41										
44	42	42	42	42										
45	45	45	45	45	45									
46	47	47	47	48	48									
47	49	50	50	50	50	50								
48		52	52	52	52	53	53							
49		54	54	55	55	56	56							
50		56	56	57	58	59	61	62						
51			59	60	61	61	63	65						
52			63	64	64	64	65	67						
53			66	67	67	68	68	69	71					
54				69	70	70	71	71	73					
55				72	74	74	74	75	77	78				
56					76	78	78	79	81	83				
57					80	82	82	82	84	88	92			
58						84	86	86	88	93	96	101		
59						87	90	90	92	96	100	103	104	
60						91	95	95	97	101	105	108	109	111
61							99	100	101	105	108	112	113	116
62							104	105	106	109	113	115	117	118
63								110	110	112	116	117	119	120
64								114	115	117	119	120	122	123
65								118	120	121	122	123	125	126
66									124	124	125	128	129	130
67									128	130	131	133	133	135
68									131	133	135	136	138	138
69										135	137	138	140	142
70										136	138	140	142	144
71										138	140	142	144	145

WIDTH-WEIGHT VALUES. The width-weight tables of Pryor and Stolz<sup>7</sup> consider skeletal width in calculating optimal weight. For children under six years of age there are seven normal weights and for children over six years of age nine normal weights. The variation from normal is based on differences in the distance between the iliac crests and, in older children, upon differences in thoracic diameter as well.

TABLE 319

## WIDTH-WEIGHT TABLES (Weight in Pounds)

(Pryor and Stolz, 1933)<sup>7</sup>

Take the age at the nearest birthday and the height at the nearest inch. Measure the width of the crests of the ilia and match it with the nearest intercrestal measurement shown for the proper age and sex group. Appropriate weight for build is read for the given height at that width. If the child is over six years of age, measure with no pressure the lateral width of the chest at the nipple level, and in the proper chest-width table opposite the height measurement and under the bi-iliac diameter measurement will be found the appropriate weight in pounds for a child of this body build.

Width measurements should be done next to the skin. This is usually possible without completely undressing the child. The weights recorded are without clothes. For school weighing with clothes, allow 1 pound for heights 38 to 40 inches and 2 pounds for heights above 40 inches.

Either sliding or accurately calibrated spreading calipers may be used to measure the bi-iliac diameter.

## Boys, Age 1 Year

Height in Inches	Inches						
	4.4	4.6	4.8	5.1	5.4	5.6	5.8
	Centimeters						
	11.3	11.8	12.2	13.1	14.0	14.4	14.9
26.....	16	16½	17	18	19	19½	20
27.....	17	17½	18	19	20	20½	21
28.....	18	18½	19	20	21	21½	22
29.....	19	19½	20	21	22	22½	23
30.....	20	20½	21	22	23	23½	24
31.....	20¾	21¼	21¾	23	24¼	24¾	25½
32.....	21½	22	22¾	24	25¼	25¾	26½
33.....	23½	24	24¾	26	27¼	27¾	28½

## Girls, Age 1 Year

Height in Inches	Inches						
	4.5	4.7	4.9	5.2	5.5	5.7	5.9
	Centimeters						
	11.5	12.0	12.4	13.3	14.2	14.6	15.1
26.....	15	15½	16	17	18	18½	19
27.....	16	16½	17	18	19	19½	20
28.....	17	17½	18	19	20	20½	21
29.....	18	18½	19	20	21	21½	22
30.....	19	19½	20	21	22	22½	23
31.....	20	20½	21	22	23	23½	24
32.....	20¾	21¼	21¾	23	24¼	24¾	25½

TABLE 319—*Continued*  
 WIDTH-WEIGHT TABLES (Weight in Pounds)  
 Boys, Age 2 Years

Height in Inches	Inches						
	4.9	5.1	5.3	5.7	6.1	6.3	6.5
	Centimeters						
	12.5	13.0	13.5	14.5	15.5	16.0	16.5
30.....	19 $\frac{3}{4}$	20 $\frac{1}{4}$	20 $\frac{3}{4}$	22	23 $\frac{1}{4}$	23 $\frac{3}{4}$	24 $\frac{1}{4}$
31.....	20 $\frac{3}{4}$	21 $\frac{1}{4}$	21 $\frac{3}{4}$	23	24 $\frac{1}{4}$	24 $\frac{3}{4}$	25 $\frac{1}{4}$
32.....	22 $\frac{1}{2}$	23	23 $\frac{3}{4}$	25	26 $\frac{1}{4}$	26 $\frac{3}{4}$	27 $\frac{1}{2}$
33.....	23 $\frac{1}{2}$	24	24 $\frac{3}{4}$	26	27 $\frac{1}{4}$	27 $\frac{3}{4}$	28 $\frac{1}{2}$
34.....	24 $\frac{1}{4}$	25	25 $\frac{3}{4}$	27	28 $\frac{1}{4}$	29	29 $\frac{3}{4}$
35.....	26	26 $\frac{3}{4}$	27 $\frac{1}{2}$	29	30 $\frac{1}{2}$	31 $\frac{1}{4}$	32
36.....	27	27 $\frac{3}{4}$	28 $\frac{1}{2}$	30	31 $\frac{1}{2}$	32 $\frac{1}{4}$	33
37.....	28 $\frac{3}{4}$	29 $\frac{3}{4}$	30 $\frac{1}{4}$	32	33 $\frac{3}{4}$	34 $\frac{1}{2}$	35 $\frac{1}{4}$

## Girls, Age 2 Years

Height in Inches	Inches						
	4.9	5.1	5.3	5.6	6.0	6.2	6.4
	Centimeters						
	12.4	13.0	13.4	14.4	15.4	15.8	16.4
30.....	19	19 $\frac{1}{2}$	20	21	22	22 $\frac{1}{2}$	23
31.....	20 $\frac{3}{4}$	21 $\frac{1}{4}$	21 $\frac{3}{4}$	23	24 $\frac{1}{4}$	24 $\frac{3}{4}$	25 $\frac{1}{4}$
32.....	21 $\frac{1}{2}$	22	22 $\frac{3}{4}$	24	25 $\frac{1}{4}$	25 $\frac{3}{4}$	26 $\frac{1}{2}$
33.....	22 $\frac{1}{2}$	23	23 $\frac{3}{4}$	25	26 $\frac{1}{4}$	26 $\frac{3}{4}$	27 $\frac{1}{2}$
34.....	23 $\frac{1}{2}$	24	24 $\frac{3}{4}$	26	27 $\frac{1}{4}$	27 $\frac{3}{4}$	28 $\frac{1}{2}$
35.....	25	25 $\frac{3}{4}$	26 $\frac{1}{2}$	28	29 $\frac{1}{2}$	30 $\frac{1}{4}$	31
36.....	27	27 $\frac{3}{4}$	28 $\frac{1}{2}$	30	31 $\frac{1}{2}$	32 $\frac{1}{4}$	33
37.....	28	28 $\frac{3}{4}$	29 $\frac{1}{2}$	31	32 $\frac{1}{2}$	33 $\frac{1}{4}$	34

TABLE 319—Continued  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Boys, Age 3 Years

Height in Inches	Inches						
	5.4	5.7	5.9	6.3	6.7	6.9	7.2
	Centimeters						
	13.8	14.4	14.9	16.0	17.1	17.6	18.2
33.....	23 $\frac{1}{2}$	24	24 $\frac{3}{4}$	26	27 $\frac{1}{4}$	27 $\frac{3}{4}$	28 $\frac{1}{2}$
34.....	24 $\frac{1}{4}$	25	25 $\frac{3}{4}$	27	28 $\frac{1}{4}$	29	29 $\frac{3}{4}$
35.....	26	26 $\frac{3}{4}$	27 $\frac{1}{2}$	29	30 $\frac{1}{2}$	31 $\frac{1}{4}$	32
36.....	28	28 $\frac{3}{4}$	29 $\frac{1}{2}$	31	32 $\frac{1}{2}$	33 $\frac{1}{4}$	34
37.....	28 $\frac{3}{4}$	29 $\frac{3}{4}$	30 $\frac{1}{4}$	32	33 $\frac{3}{4}$	34 $\frac{1}{2}$	35 $\frac{1}{4}$
38.....	29 $\frac{3}{4}$	30 $\frac{1}{2}$	31 $\frac{1}{4}$	33	34 $\frac{3}{4}$	35 $\frac{1}{2}$	36 $\frac{1}{4}$
39.....	31 $\frac{1}{2}$	32 $\frac{3}{4}$	33 $\frac{1}{4}$	35	36 $\frac{3}{4}$	37 $\frac{3}{4}$	38 $\frac{1}{2}$
40.....	32 $\frac{1}{2}$	33 $\frac{1}{2}$	34 $\frac{1}{4}$	36	37 $\frac{3}{4}$	38 $\frac{3}{4}$	39 $\frac{1}{2}$

Girls, Age 3 Years

Height in Inches	Inches						
	5.3	5.6	5.8	6.2	6.6	6.8	7.1
	Centimeters						
	13.7	14.3	14.8	15.9	17.0	17.5	18.1
32.....	22 $\frac{1}{2}$	23	23 $\frac{3}{4}$	25	26 $\frac{1}{4}$	26 $\frac{3}{4}$	27 $\frac{1}{2}$
33.....	23 $\frac{1}{2}$	24	24 $\frac{3}{4}$	26	27 $\frac{1}{4}$	27 $\frac{3}{4}$	28 $\frac{1}{2}$
34.....	24 $\frac{1}{4}$	25	25 $\frac{3}{4}$	27	28 $\frac{1}{4}$	29	29 $\frac{3}{4}$
35.....	26	26 $\frac{3}{4}$	27 $\frac{1}{2}$	29	30 $\frac{1}{2}$	31 $\frac{1}{4}$	32
36.....	27	27 $\frac{3}{4}$	28 $\frac{1}{2}$	30	31 $\frac{1}{2}$	32 $\frac{1}{4}$	33
37.....	28	28 $\frac{3}{4}$	29 $\frac{1}{2}$	31	32 $\frac{1}{2}$	33 $\frac{1}{4}$	34
38.....	29 $\frac{3}{4}$	30 $\frac{1}{2}$	31 $\frac{1}{4}$	33	34 $\frac{3}{4}$	35 $\frac{1}{2}$	36 $\frac{1}{4}$
39.....	30 $\frac{1}{2}$	31 $\frac{1}{2}$	32 $\frac{1}{4}$	34	35 $\frac{3}{4}$	36 $\frac{1}{2}$	37 $\frac{1}{2}$
40.....	31 $\frac{1}{2}$	32 $\frac{3}{4}$	33 $\frac{1}{4}$	35	36 $\frac{3}{4}$	37 $\frac{3}{4}$	38 $\frac{1}{2}$

TABLE 319—*Continued*  
 WIDTH-WEIGHT TABLES (Weight in Pounds)  
 Boys, Age 4 Years

Height in Inches	Inches						
	5.8	6.1	6.3	6.75	7.2	7.4	7.7
	Centimeters						
	14.8	15.5	16.0	17.2	18.4	18.9	19.6
35.....	26	26 $\frac{3}{4}$	27 $\frac{1}{2}$	29	30 $\frac{1}{2}$	31 $\frac{1}{4}$	32
36.....	28	28 $\frac{3}{4}$	29 $\frac{1}{2}$	31	32 $\frac{1}{2}$	33 $\frac{1}{4}$	34
37.....	28 $\frac{3}{4}$	29 $\frac{3}{4}$	30 $\frac{1}{4}$	32	33 $\frac{3}{4}$	34 $\frac{1}{2}$	35 $\frac{1}{4}$
38.....	29 $\frac{3}{4}$	30 $\frac{1}{2}$	31 $\frac{1}{4}$	33	34 $\frac{3}{4}$	35 $\frac{1}{2}$	36 $\frac{1}{4}$
39.....	31 $\frac{1}{2}$	32 $\frac{3}{4}$	33 $\frac{1}{4}$	35	36 $\frac{3}{4}$	37 $\frac{3}{4}$	38 $\frac{1}{2}$
40.....	32 $\frac{1}{2}$	33 $\frac{1}{2}$	34 $\frac{1}{4}$	36	37 $\frac{3}{4}$	38 $\frac{3}{4}$	39 $\frac{1}{2}$
41.....	34 $\frac{1}{4}$	35 $\frac{1}{2}$	36 $\frac{1}{4}$	38	39 $\frac{3}{4}$	40 $\frac{3}{4}$	41 $\frac{3}{4}$
42.....	35	36	37	39	41	42	43
43.....	37	38	39	41	43	44	45

## Girls, Age 4 Years

Height in Inches	Inches						
	5.9	6.1	6.3	6.8	7.3	7.5	7.7
	Centimeters						
	15.1	15.6	16.1	17.3	18.5	19.0	19.5
35.....	26	26 $\frac{3}{4}$	27 $\frac{1}{2}$	29	30 $\frac{1}{2}$	31 $\frac{1}{4}$	32
36.....	27	27 $\frac{3}{4}$	28 $\frac{1}{2}$	30	31 $\frac{1}{2}$	32 $\frac{1}{4}$	33
37.....	28	28 $\frac{3}{4}$	29 $\frac{1}{2}$	31	32 $\frac{1}{2}$	33 $\frac{1}{4}$	34
38.....	29 $\frac{3}{4}$	30 $\frac{1}{2}$	31 $\frac{1}{4}$	33	34 $\frac{3}{4}$	35 $\frac{1}{2}$	36 $\frac{1}{4}$
39.....	30 $\frac{1}{2}$	31 $\frac{1}{2}$	32 $\frac{1}{4}$	34	35 $\frac{3}{4}$	36 $\frac{1}{2}$	37 $\frac{1}{2}$
40.....	32 $\frac{1}{2}$	33 $\frac{1}{2}$	34 $\frac{1}{4}$	36	37 $\frac{3}{4}$	38 $\frac{3}{4}$	39 $\frac{1}{2}$
41.....	33 $\frac{1}{4}$	34 $\frac{1}{4}$	35 $\frac{1}{4}$	37	38 $\frac{1}{4}$	39 $\frac{3}{4}$	40 $\frac{3}{4}$
42.....	35	36	37	39	41	42	43
43.....	36	37	38	40	42	43	44

TABLE 319—Continued  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Boys, Age 5 Years

Height in Inches	Inches						
	6.1	6.4	6.6	7.1	7.6	7.8	8.1
	Centimeters						
	15.6	16.3	16.8	18.1	19.4	19.9	20.6
37.....	28 $\frac{3}{4}$	29 $\frac{3}{4}$	30 $\frac{1}{4}$	32	33 $\frac{3}{4}$	34 $\frac{1}{2}$	35 $\frac{1}{4}$
38.....	30 $\frac{1}{2}$	31 $\frac{1}{2}$	32 $\frac{1}{4}$	34	35 $\frac{3}{4}$	36 $\frac{3}{4}$	37 $\frac{1}{2}$
39.....	31 $\frac{1}{2}$	32 $\frac{3}{4}$	33 $\frac{1}{4}$	35	36 $\frac{3}{4}$	37 $\frac{3}{4}$	38 $\frac{1}{2}$
40.....	32 $\frac{1}{2}$	33 $\frac{1}{2}$	34 $\frac{1}{4}$	36	37 $\frac{3}{4}$	38 $\frac{3}{4}$	39 $\frac{1}{2}$
41.....	34 $\frac{1}{4}$	35 $\frac{1}{2}$	36 $\frac{1}{4}$	38	39 $\frac{3}{4}$	40 $\frac{3}{4}$	41 $\frac{3}{4}$
42.....	35	36	37	39	41	42	43
43.....	37	38	39	41	43	44	45
44.....	38 $\frac{3}{4}$	39 $\frac{3}{4}$	40 $\frac{3}{4}$	43	45 $\frac{1}{4}$	46 $\frac{1}{4}$	47 $\frac{1}{4}$
45.....	40 $\frac{1}{2}$	41 $\frac{1}{2}$	42 $\frac{3}{4}$	45	47 $\frac{1}{2}$	48 $\frac{1}{4}$	49 $\frac{1}{2}$

Girls, Age 5 Years

Height in Inches	Inches						
	6.0	6.2	6.4	6.9	7.4	7.6	7.8
	Centimeters						
	15.2	15.8	16.4	17.6	18.8	19.4	20.0
36.....	28	28 $\frac{3}{4}$	29 $\frac{1}{2}$	31	32 $\frac{1}{2}$	33 $\frac{1}{4}$	34
37.....	28 $\frac{3}{4}$	29 $\frac{3}{4}$	30 $\frac{1}{4}$	32	33 $\frac{3}{4}$	34 $\frac{1}{2}$	35 $\frac{1}{4}$
38.....	29 $\frac{3}{4}$	30 $\frac{1}{2}$	31 $\frac{1}{4}$	33	34 $\frac{3}{4}$	35 $\frac{1}{2}$	36 $\frac{1}{4}$
39.....	30 $\frac{1}{2}$	31 $\frac{1}{2}$	32 $\frac{1}{4}$	34	35 $\frac{3}{4}$	36 $\frac{1}{2}$	37 $\frac{1}{2}$
40.....	32 $\frac{1}{2}$	33 $\frac{1}{2}$	34 $\frac{1}{4}$	36	37 $\frac{3}{4}$	38 $\frac{3}{4}$	39 $\frac{1}{2}$
41.....	33 $\frac{1}{4}$	34 $\frac{1}{4}$	35 $\frac{1}{4}$	37	38 $\frac{3}{4}$	39 $\frac{3}{4}$	40 $\frac{3}{4}$
42.....	35	36	37	39	41	42	43
43.....	37	38	39	41	43	44	45
44.....	37 $\frac{3}{4}$	38 $\frac{3}{4}$	39 $\frac{3}{4}$	42	44 $\frac{1}{4}$	45 $\frac{1}{2}$	46 $\frac{1}{4}$

TABLE 319—*Continued*  
 WIDTH-WEIGHT TABLES (Weight in Pounds)  
 Boys, Age 6 Years

Narrow Chest								Medium Chest								Broad Chest							
Thoracic Lateral Width, 17.5 Cm. and Below				Thoracic Lateral Width, 17.6 to 19.8 Cm.				Thoracic Lateral Width, 19.9 Cm. and Above															
Hgt. in Ins.				Hgt. in Ins.				Hgt. in Ins.				Hgt. in Ins.											
Width of Bi-iliac Diameter in Centimeters				Width of Bi-iliac Diameter in Centimeters				Width of Bi-iliac Diameter in Centimeters				Width of Bi-iliac Diameter in Centimeters											
13.9	15.4	16.4	18.5	20.6	21.6	23.1	13.9	15.4	16.4	18.5	20.6	21.6	23.1	13.9	15.4	16.4	18.5	20.6	21.6	23.1			
38.	25	26	27	29	30	31	32	28	29	30	31	33	34	35	38.	29	31	33	35	35	36		
39.	27	28	29	31	32	33	34	30	31	32	33	35	36	37	39.	31	33	33	37	37	38		
40.	29	30	31	33	34	35	36	32	33	34	35	37	38	39	40.	33	35	35	39	39	40		
41.	31	32	33	35	36	37	38	34	35	36	37	39	40	41	41.	35	36	37	40	41	42		
42.	33	34	35	37	38	39	40	36	37	38	39	41	42	43	42.	37	38	39	42	43	44		
43.	35	36	37	39	40	41	42	38	39	40	41	43	44	45	43.	39	40	41	44	45	46		
44.	37	38	39	41	42	43	44	40	41	42	43	45	46	47	44.	41	42	43	46	47	48		
45.	39	40	41	43	44	45	46	42	43	44	45	47	48	49	45.	43	44	45	48	49	50		
46.	41	42	43	45	46	47	48	44	45	46	47	49	50	51	46.	45	46	47	50	51	52		
47.	43	44	45	47	48	49	50	46	47	48	49	51	52	53	47.	47	48	49	52	53	54		
48.	45	46	47	49	50	51	52	48	49	49	51	53	54	55	48.	49	51	53	54	55	56		
49.	47	48	49	51	52	53	54	50	51	51	53	55	55	57	49.	51	52	53	56	57	58		
50.	49	50	51	53	54	55	56	52	53	53	55	57	57	59	50.	53	54	55	58	59	60		

TABLE 319—Continued

## WIDTH-WEIGHT TABLES (Weight in Pounds)

Girls, Age 6 Years

Narrow Chest								Medium Chest								Broad Chest							
Thoracic Lateral Width, 16.9 Cm. and Below				Thoracic Lateral Width, 17.0 to 19.0 Cm.				Thoracic Lateral Width, 19.1 Cm. and Above															
Hgt. in Ins.				Hgt. in Ins.				Hgt. in Ins.															
Width of Bi-iliac Diameter in Centimeters				Width of Bi-iliac Diameter in Centimeters				Width of Bi-iliac Diameter in Centimeters															
13.9	15.3	16.2	18.3	20.4	21.3	22.8	13.9	15.3	16.2	18.3	20.4	21.3	22.8	13.9	15.3	16.2	18.3	20.4	21.3	22.8			
38....	29	32	34	37	41	43	46	38....	30	33	35	38	42	44	47	38....	32	35	37	40	44	46	49
39....	30	33	35	38	42	44	47	39....	31	34	36	39	43	45	48	39....	34	36	38	42	45	47	50
40....	31	34	36	39	43	45	48	40....	32	35	37	40	44	46	49	40....	35	37	39	43	46	48	51
41....	32	35	37	40	44	46	49	41....	34	36	38	42	45	47	50	41....	36	38	40	44	47	49	52
42....	34	36	38	42	45	47	50	42....	35	37	39	43	46	48	51	42....	37	39	41	45	48	50	53
43....	35	37	39	43	46	48	51	43....	36	38	40	44	47	49	52	43....	38	40	42	46	49	51	54
44....	36	38	40	44	47	49	52	44....	37	39	41	45	48	50	53	44....	39	41	43	47	50	52	55
45....	37	39	41	45	48	50	53	45....	38	40	42	46	50	51	54	45....	40	42	44	48	51	53	56
46....	38	40	42	46	50	51	54	46....	39	41	43	47	51	52	55	46....	41	43	45	49	53	54	57
47....	39	41	43	47	51	52	55	47....	40	42	44	48	52	53	56	47....	42	44	46	50	54	55	58
48....	40	42	44	48	52	53	56	48....	41	43	45	49	53	54	57	48....	43	45	47	51	55	56	59
49....	41	43	45	49	53	54	57	49....	42	44	46	50	54	55	58	49....	44	47	48	52	56	57	60
50....	42	44	46	50	54	55	58	50....	43	45	47	51	55	56	59	50....	45	48	49	53	57	58	61

TABLE. 319—Continued  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Boys, Age 7 Years

Narrow Chest						Medium Chest						Broad Chest											
Hgt. in Ins.	Thoracic Lateral Width, 18.2 Cm. and Below						Hgt. in Ins.	Thoracic Lateral Width, 18.3 to 20.7 Cm.						Hgt. in Ins.	Thoracic Lateral Width, 20.8 Cm. and Above								
	Width of Bi-iliac Diameter in Centimeters							Width of Bi-iliac Diameter in Centimeters							Width of Bi-iliac Diameter in Centimeters								
	14.5	16.1	17.1	19.3	21.5	22.5		24.1	14.5	16.1	17.1	19.3	21.5		22.5	24.1	14.5	16.1	17.1	19.3	21.5	22.5	24.1
41.	35	37	37	39	41	42	43	41.	41	42	43	44	46	47	48	41.	47	48	49	50	52	53	54
42.	37	38	39	40	42	43	44	42.	42	43	44	46	48	48	50	42.	48	49	50	52	53	54	55
43.	38	39	40	42	43	44	45	43.	43	45	45	47	49	50	51	43.	49	51	51	53	55	56	57
44.	39	41	41	43	45	46	47	44.	45	46	47	49	50	52	52	44.	51	52	53	54	56	57	58
45.	41	42	43	45	46	47	48	45.	46	47	48	50	52	52	54	45.	52	53	54	56	58	58	60
46.	42	43	44	46	48	48	50	46.	48	49	50	51	53	54	55	46.	54	55	56	57	59	60	61
47.	44	45	46	47	49	50	51	47.	49	50	51	53	54	55	56	47.	55	56	57	59	60	61	62
48.	45	46	47	49	50	51	52	48.	50	52	52	54	56	57	58	48.	56	58	58	60	62	62	64
49.	46	48	48	50	52	53	54	49.	52	53	54	55	57	58	59	49.	58	59	60	61	63	64	65
50.	48	49	50	51	53	54	55	50.	53	54	55	57	59	59	61	50.	59	60	61	63	64	65	66
51.	49	50	51	53	55	55	57	51.	55	56	57	58	60	61	62	51.	60	62	62	64	66	67	68
52.	51	52	53	54	56	57	58	52.	56	57	58	60	61	62	63	52.	62	63	64	66	67	68	69
53.	52	53	54	56	57	58	59	53.	57	59	59	61	63	63	65	53.	63	64	65	67	69	69	71

TABLE 319—*Continued*  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Girls, Age 7 Years

Narrow Chest				Medium Chest				Broad Chest							
Hgt. in Ins.	Thoracic Lateral Width, 17.6 Cm. and Below				Hgt. in Ins.	Thoracic Lateral Width, 17.7 to 20.5 Cm.				Hgt. in Ins.	Thoracic Lateral Width, 20.6 Cm. and Above				
	Width of Bi-iliac Diameter in Centimeters					Width of Bi-iliac Diameter in Centimeters					Width of Bi-iliac Diameter in Centimeters				
	14.3	15.9	16.8	19.0		21.2	22.1	23.7	14.3		15.9	16.8	19.0	21.2	22.1
40....	28	31	33	38	42	44	48	40....	31	34	36	41	45	47	51
41....	29	32	34	39	44	46	49	41....	32	35	37	42	47	49	52
42....	30	34	36	40	45	47	50	42....	33	37	39	43	48	50	53
43....	31	35	37	42	46	48	52	43....	35	38	40	45	49	51	55
44....	33	36	38	43	47	49	53	44....	36	39	41	46	51	52	56
45....	34	37	39	44	49	51	54	45....	37	41	42	47	52	54	57
46....	35	39	41	45	50	52	55	46....	38	42	44	48	53	55	58
47....	37	40	42	47	51	53	57	47....	40	43	45	50	54	56	60
48....	38	41	43	48	53	55	58	48....	41	44	46	51	56	58	61
49....	39	43	44	49	54	56	59	49....	42	46	48	52	57	59	62
50....	40	44	46	50	55	57	60	50....	43	47	49	54	58	60	64
51....	42	45	47	52	56	58	62	51....	45	48	50	55	59	61	65
52....	43	46	48	53	58	60	63	52....	46	49	51	56	61	63	66
53....	44	48	50	54	59	61	64	53....	47	51	53	57	62	64	67

TABLE 319—Continued  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Boys, Age 8 Years

Narrow Chest										Medium Chest										Broad Chest									
Hgt. in Ins.	Thoracic Lateral Width, 18.2 Cm. and Below								Hgt. in Ins.	Thoracic Lateral Width, 18.3 to 21.1 Cm.								Hgt. in Ins.	Thoracic Lateral Width, 21.2 Cm. and Above										
	Width of Bi-iliac Diameter in Centimeters									Width of Bi-iliac Diameter in Centimeters									Width of Bi-iliac Diameter in Centimeters										
	15.3	17.0	18.0	20.3	22.6	23.6	25.3	15.3		17.0	18.0	20.3	22.6	23.6	25.3	15.3	17.0		18.0	20.3	22.6	23.6	25.3						
42.	35	38	40	42	44	49	54	42.	37	41	43	46	49	54	58	42.	40	44	46	50	55	57	61	61					
43.	37	40	41	43	45	51	55	43.	38	42	44	47	51	55	59	43.	41	45	47	52	57	58	62	62					
44.	38	41	42	44	47	52	56	44.	39	43	45	48	52	56	60	44.	42	46	48	53	58	59	63	63					
45.	39	43	44	46	48	53	57	45.	40	44	46	50	53	57	61	45.	43	47	49	54	59	60	64	64					
46.	41	44	45	47	49	55	58	46.	42	46	48	51	55	58	62	46.	45	49	51	56	61	62	66	66					
47.	43	46	47	48	51	56	59	47.	43	47	49	52	56	60	64	47.	46	50	52	57	62	63	67	67					
48.	44	47	48	50	52	58	61	48.	45	49	51	54	58	62	66	48.	48	52	54	58	63	65	69	69					
49.	45	48	49	51	54	60	63	49.	46	50	52	55	59	63	67	49.	49	53	55	60	65	66	70	70					
50.	47	50	51	52	55	61	64	50.	48	52	54	57	60	65	69	50.	51	55	57	61	66	68	72	72					
51.	49	51	52	54	56	63	66	51.	49	53	55	58	62	66	70	51.	53	57	59	63	68	70	74	74					
52.	50	53	54	55	58	64	67	52.	51	55	57	60	63	68	72	52.	55	58	60	65	69	71	75	75					
53.	51	54	55	57	59	66	69	53.	53	57	59	61	64	70	74	53.	56	60	62	66	70	72	76	76					
54.	52	55	57	58	60	67	70	54.	54	58	60	62	65	71	75	54.	57	61	63	67	72	74	78	80					
55.	53	57	58	60	62	68	72	55.	56	60	62	64	67	73	77	55.	58	63	65	69	74	76	82	82					
56.	54	58	59	61	63	69	73	56.	57	61	63	66	68	74	78	56.	59	65	67	71	76	78	83	83					

TABLE 319—Continued  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Girls, Age 8 Years

Narrow Chest										Medium Chest										Broad Chest												
Hgt. in Ins.	Thoracic Lateral Width, 18.1 Cm. and Below										Hgt. in Ins.	Thoracic Lateral Width, 18.2 to 20.8 Cm.										Hgt. in Ins.	Thoracic Lateral Width, 20.9 Cm. and Above									
	Width of Bi-iliac Diameter in Centimeters											Width of Bi-iliac Diameter in Centimeters											Width of Bi-iliac Diameter in Centimeters									
	15.3	17.0	18.0	20.3	22.6	23.6	25.3	15.3	17.0	18.0		20.3	22.6	23.6	25.3	15.3	17.0	18.0	20.3	22.6	23.6	25.3										
43....	32	37	39	45	51	53	58	43....	35	40	42	48	54	56	61	43.	39	44	46	52	58	60	65									
44....	33	38	40	46	52	54	59	44....	36	41	43	49	55	57	62	44.	40	45	47	53	59	61	66									
45....	34	39	41	47	53	55	61	45....	37	42	44	50	56	58	63	45.	41	46	48	54	60	62	67									
46....	35	40	42	48	54	57	62	46....	38	43	45	51	57	59	64	46.	42	47	49	55	61	63	68									
47....	37	42	44	50	56	58	64	47.	39	44	46	52	58	60	65	47....	43	48	50	56	62	64	69									
48....	38	43	45	51	57	59	65	48.	40	45	47	53	59	61	66	48.	44	49	51	57	63	65	70									
49....	39	44	46	52	58	60	66	49.	41	46	48	54	60	62	67	49....	46	51	53	59	65	67	72									
50....	40	45	47	53	59	61	67	50.	43	48	50	56	62	64	69	50....	47	52	54	60	66	68	73									
51....	42	46	48	54	60	62	68	51.	44	49	51	57	63	65	70	51....	48	53	55	61	67	69	74									
52....	43	47	49	55	61	63	69	52.	45	50	52	58	64	66	71	52....	50	55	57	63	69	71	76									
53....	44	48	50	56	62	64	70	53.	46	51	53	59	65	67	72	53....	51	56	58	64	70	72	77									
54....	45	50	52	58	64	66	72	54.	47	52	54	60	66	68	73	54....	52	57	59	65	71	73	78									
55....	47	51	53	59	65	67	73	55....	48	53	55	61	67	69	74	55....	54	59	61	67	73	75	80									

TABLE 319—Continued

## WIDTH-WEIGHT TABLES (Weight in Pounds)

Boys, Age 9 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 18.7 Cm. and Below										Thoracic Lateral Width, 18.6 to 21.6 Cm.										Thoracic Lateral Width, 21.7 Cm. and Above									
Width of Bi-iliac Diameter in Centimeters										Width of Bi-iliac Diameter in Centimeters										Width of Bi-iliac Diameter in Centimeters									
Hgt. in Ins.										Hgt. in Ins.										Hgt. in Ins.									
16.6	18.1	19.0	20.0	21.1	22.1	23.2	24.1	25.6		16.6	18.1	19.0	20.0	21.1	22.1	23.2	24.1	25.6		16.6	18.1	19.0	20.0	21.1	22.1	23.2	24.1	25.6	
39	42	44	46	49	51	53	55	58	45	43	46	48	50	52	54	57	59	62	45	46	49	51	53	55	57	60	62	65	67
41	44	46	48	50	52	55	57	60	46	44	48	49	52	54	56	58	60	63	46	47	51	53	55	57	59	62	63	65	67
47	46	47	50	52	54	56	58	61	47	46	49	51	54	56	58	60	62	65	47	49	52	54	57	59	61	63	65	67	68
48	47	49	52	54	56	58	60	63	48	48	51	53	55	57	59	62	63	67	48	51	54	56	58	60	62	65	67	70	71
49	46	49	51	53	55	58	60	61	49	49	52	54	57	59	61	63	65	68	49	52	55	57	60	62	64	66	68	70	73
50	47	50	52	55	57	59	61	63	50	51	54	56	58	60	62	64	66	68	50	54	57	59	61	63	65	67	69	71	75
51	49	52	54	56	58	60	63	65	51	52	55	57	60	62	64	66	68	70	51	55	59	61	63	65	67	69	71	73	76
52	50	53	55	58	60	62	64	66	52	54	57	59	61	63	65	67	70	72	52	57	60	62	64	66	68	70	73	75	78
53	52	55	57	59	61	64	66	68	53	55	59	61	63	65	67	69	71	73	53	59	62	64	66	68	70	72	74	76	79
54	53	57	59	61	63	66	68	69	54	57	60	62	65	67	69	71	73	75	54	60	63	65	68	70	72	74	76	78	81
55	55	58	60	63	65	67	69	71	55	59	62	64	66	68	70	73	75	78	55	62	65	67	69	71	73	75	77	79	83
56	57	60	62	64	66	68	71	73	56	60	63	65	68	70	72	74	76	79	56	63	67	69	71	73	75	77	79	81	84
57	58	61	63	66	68	70	72	74	57	62	65	67	69	71	73	76	78	81	57	65	68	70	73	75	77	79	81	84	86
58	60	63	65	67	69	72	74	76	58	63	67	69	71	73	75	77	79	83	58	67	70	72	74	76	78	81	83	86	88

TABLE 319—Continued

WIDTH-WEIGHT TABLES (Weight in Pounds)  
Girls, Age 9 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 18.5 Cm. and Below										Thoracic Lateral Width, 18.6 to 21.2 Cm.										Thoracic Lateral Width, 21.3 Cm. and Above									
Width of Bi-iliac Diameter in Centimeters										Width of Bi-iliac Diameter in Centimeters										Width of Bi-iliac Diameter in Centimeters									
Hgt. in Ins.	16.6	18.1	19.0	20.0	21.1	22.1	23.2	24.1	25.6	Hgt. in Ins.	16.6	18.1	19.0	20.0	21.1	22.1	23.2	24.1	25.6	Hgt. in Ins.	16.6	18.1	19.0	20.0	21.1	22.1	23.2	24.1	25.6
45	37	41	44	47	50	53	56	59	63	45	43	48	51	55	59	62	66	69	74	45	49	54	57	62	65	68	73	76	81
46	38	42	45	48	51	54	57	60	64	46	44	49	52	56	60	63	67	70	75	46	50	55	58	63	66	69	74	77	82
47	39	43	46	49	52	55	58	61	65	47	45	50	53	57	61	64	68	71	76	47	51	56	59	64	67	70	75	78	83
48	40	44	47	50	53	56	59	62	66	48	46	51	54	58	62	65	69	72	77	48	52	57	60	65	68	71	76	79	84
49	41	45	48	51	54	57	60	63	67	49	47	52	55	59	63	66	70	73	78	49	53	58	61	66	69	72	77	80	85
50	42	46	49	52	55	58	61	64	68	50	48	53	56	60	64	67	71	74	79	50	54	59	62	67	70	73	78	81	86
51	43	47	50	53	56	59	62	65	69	51	49	54	57	61	65	68	72	75	80	51	55	60	63	68	71	74	79	82	87
52	44	48	51	54	57	60	63	66	70	52	50	55	58	62	66	69	73	76	81	52	56	61	64	69	72	75	80	83	88
53	45	49	52	55	58	61	64	67	71	53	51	56	59	63	67	70	74	77	82	53	57	62	65	70	73	76	81	84	89
54	46	50	53	56	59	62	65	68	72	54	52	57	60	64	68	71	75	78	83	54	58	63	66	71	74	77	82	85	90
55	47	51	54	57	60	63	66	69	73	55	53	58	61	65	69	72	76	79	84	55	59	64	67	72	75	78	83	86	91
56	48	52	55	58	61	64	67	70	74	56	54	59	62	66	70	73	77	80	85	56	60	65	68	73	76	79	84	87	92
57	49	53	56	59	62	65	68	71	75	57	55	60	63	67	71	74	78	81	86	57	61	66	69	74	77	80	85	88	93

TABLE 319—Continued

WIDTH-WEIGHT TABLES (Weight in Pounds)

Boys, Age 10 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 20.0 Cm. and Below										Thoracic Lateral Width, 20.1 to 22.7 Cm.										Thoracic Lateral Width, 22.8 Cm. and Above									
Hgt. in Ins.										Hgt. in Ins.										Hgt. in Ins.									
Width of Bi-iliac Diameter in Centimeters										Width of Bi-iliac Diameter in Centimeters										Width of Bi-iliac Diameter in Centimeters									
17.0	18.5	19.4	20.5	21.6	22.7	23.8	24.7	26.2		17.0	18.5	19.4	20.5	21.6	22.7	23.8	24.7	26.2		17.0	18.5	19.4	20.5	21.6	22.7	23.8	24.7	26.2	
47..	40	44	46	48	51	54	57	59	63	47..	47	51	53	55	58	61	64	66	70	47	53	57	59	62	65	68	70	72	76
48..	42	45	48	50	53	56	59	61	65	48..	49	52	55	57	60	63	66	68	71	48	55	59	61	63	66	69	72	74	78
49..	43	47	49	52	55	58	60	62	66	49..	50	54	56	59	62	65	67	69	73	49	57	60	63	65	68	71	73	76	79
50..	45	49	51	53	56	59	62	64	68	50..	52	56	58	60	63	66	69	71	75	50	58	62	64	67	70	73	75	77	81
51..	47	50	53	55	58	61	64	66	70	51..	54	57	60	62	65	68	71	73	77	51	60	64	66	68	71	74	77	79	83
52..	48	52	54	57	60	63	65	68	71	52..	55	59	61	64	67	70	72	74	78	52	62	65	68	70	73	76	79	81	84
53..	50	54	56	58	61	64	67	69	73	53..	57	61	63	65	68	71	74	76	80	53	63	67	69	72	75	78	80	82	86
54..	52	55	58	60	63	66	69	71	75	54..	59	62	65	67	70	73	76	78	82	54	65	69	71	73	76	79	82	84	88
55..	53	57	59	62	65	68	70	73	76	55..	60	64	66	69	72	75	77	80	83	55	67	70	73	75	78	81	84	86	89
56..	55	59	61	64	67	70	72	74	78	56..	62	66	68	70	73	76	79	81	85	56	68	72	74	77	80	83	85	87	91
57..	57	60	63	65	68	71	74	76	80	57..	64	67	70	72	75	78	81	83	87	57	70	74	76	78	81	84	87	89	93
58..	58	62	64	67	70	73	75	78	81	58..	65	69	71	74	77	80	82	85	88	58	72	75	78	80	83	86	89	91	95
59..	60	64	66	69	72	75	77	79	83	59..	67	71	73	75	78	81	84	86	90	59	73	77	79	82	85	88	90	92	96
60..	62	66	68	70	73	76	79	81	85	60..	69	72	75	77	80	83	86	88	92	60	75	79	81	83	86	89	92	94	98

TABLE 319—Continued  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Girls, Age 10 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 19.6 Cm. and Below										Thoracic Lateral Width, 19.7 to 22.9 Cm.										Thoracic Lateral Width, 23.0 Cm. and Above									
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters								
	18.4	19.7	20.4	21.2	22.1	22.9	23.8	24.5	25.8		18.4	19.7	20.4	21.2	22.1	22.9	23.8	24.5	25.8		18.4	19.7	20.4	21.2	22.1	22.9	23.8	24.5	25.8
47	43	46	48	50	52	54	56	58	61	47	50	53	55	57	59	61	63	65	68	47	58	61	63	65	67	69	72	73	77
48	45	48	50	52	54	56	58	60	63	48	52	55	57	59	61	63	65	67	70	48	60	63	65	67	69	71	73	75	78
49	47	50	52	54	56	58	60	62	65	49	53	57	58	61	63	65	67	69	72	49	62	65	67	69	71	73	75	77	80
50	48	52	53	56	58	60	62	63	67	50	55	58	60	62	64	66	69	70	74	50	64	67	68	71	73	75	77	79	82
51	50	53	55	57	59	61	63	65	68	51	57	60	62	64	66	68	70	72	75	51	65	69	70	72	74	76	79	80	84
52	52	55	57	59	61	63	65	67	70	52	59	62	64	66	68	70	72	74	77	52	67	70	72	74	76	78	80	82	85
53	54	57	59	61	63	65	67	69	72	53	61	64	66	68	70	72	74	76	79	53	69	72	74	76	78	80	82	84	87
54	56	59	60	63	65	67	69	71	74	54	62	66	67	70	72	74	76	77	81	54	71	74	76	78	80	82	84	86	89
55	57	61	62	64	66	68	71	72	76	55	64	67	69	71	73	75	78	79	82	55	72	76	77	80	82	84	86	88	91
56	59	62	64	66	68	70	72	74	77	56	66	69	71	73	75	77	79	81	84	56	74	77	79	81	83	85	88	89	93
57	61	64	66	68	70	72	74	76	79	57	68	71	73	75	77	79	81	83	86	57	76	79	81	83	85	87	89	91	94
58	63	66	68	70	72	74	76	78	81	58	69	73	74	77	79	81	83	85	88	58	78	81	83	85	87	89	91	93	96
59	64	68	69	72	74	76	78	80	83	59	71	74	76	78	80	82	85	86	90	59	80	83	84	87	89	91	93	95	98
60	66	69	71	73	75	77	80	81	85	60	73	76	78	80	82	84	86	88	91	60	81	85	86	88	90	92	95	96	100

TABLE 319.—*Continued*  
 WIDTH-WEIGHT TABLES (Weight in Pounds)  
 Boys, Age 11 Years

Narrow Chest										Medium Chest										Broad Chest																										
Thoracic Lateral Width, 20.3 Cm. and Below										Thoracic Lateral Width, 20.4 to 23.4 Cm.										Thoracic Lateral Width, 23.5 Cm. and Above																										
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters																									
	18.1	19.5	20.4	21.3	22.3	23.2	24.2	25.1	26.5		18.1	19.5	20.4	21.3	22.3	23.2	24.2	25.1	26.5		18.1	19.5	20.4	21.3	22.3	23.2	24.2	25.1	26.5																	
49	46	50	52	55	58	61	63	66	70	49	53	57	60	62	65	68	71	73	77	49	62	66	68	71	74	77	79	82	85	87	82	79	77	74	71	68	66	62	59	55	51	48				
50	48	52	54	57	60	63	65	67	71	50	55	59	62	64	67	70	72	75	79	50	63	67	70	72	75	78	81	83	86	87	83	81	78	75	72	70	67	63	60	57	53	49				
51	49	53	56	58	61	64	67	69	73	51	57	61	63	66	69	72	74	77	81	51	65	69	72	74	77	80	82	84	86	85	83	80	77	74	72	70	67	63	60	57	53	49				
52	51	55	58	60	63	67	69	71	75	52	59	63	65	68	71	74	76	79	83	52	67	71	74	76	79	82	84	86	87	84	82	79	76	74	72	70	67	63	60	57	53	49				
53	53	57	60	62	65	68	70	73	77	53	60	64	67	69	72	75	78	80	84	53	69	73	75	78	81	84	86	88	89	86	84	81	78	75	73	70	67	63	60	57	53	49				
54	55	59	61	64	67	70	72	75	79	54	62	66	69	71	74	77	80	82	86	54	71	75	77	80	83	86	88	91	93	91	88	85	82	79	77	74	71	67	63	60	56	52				
55	57	61	63	66	69	72	74	77	81	55	64	68	71	73	76	79	81	84	88	55	72	76	79	81	84	87	90	92	96	92	90	87	84	81	78	76	73	70	66	62	58	54				
56	58	62	65	67	70	73	76	78	82	56	66	70	72	75	78	81	83	86	90	56	74	78	81	83	86	89	92	94	98	94	91	88	85	83	80	78	75	72	68	64	60	56				
57	60	64	67	69	72	75	78	80	84	57	68	72	74	77	80	83	85	88	92	57	76	80	83	85	88	91	93	96	100	96	93	90	88	85	83	80	78	75	72	68	64	60				
58	62	66	68	71	74	77	79	82	86	58	69	73	76	78	81	84	87	89	93	58	78	82	84	87	90	93	95	98	102	98	95	92	90	88	85	83	80	78	75	72	68	64				
59	64	68	69	73	76	79	81	84	88	59	71	75	78	80	83	86	89	91	95	59	80	84	86	89	92	95	97	100	104	100	97	94	92	90	88	85	83	80	78	75	72	68	64			
60	66	70	71	75	78	81	83	86	90	60	73	77	80	82	85	88	90	93	97	60	81	85	88	90	93	96	99	101	105	101	98	96	94	92	90	88	85	83	80	78	75	72	68	64		
61	67	71	72	76	79	82	85	87	91	61	75	79	81	84	87	90	92	95	99	61	83	87	90	92	95	98	101	103	107	103	101	99	97	95	93	91	89	87	85	82	79	76	72	68	64	
62	69	73	74	78	81	84	87	89	93	62	77	81	83	86	89	92	94	97	101	62	85	89	92	94	97	100	102	105	109	105	102	100	98	96	94	92	90	88	85	82	79	76	72	68	64	
63	71	75	76	80	83	87	88	91	95	63	79	83	85	88	91	94	96	98	102	63	87	91	93	96	99	102	104	107	111	107	104	102	100	98	96	94	92	90	88	85	82	79	76	72	68	64

TABLE 319—Continued

WIDTH-WEIGHT TABLES (Weight in Pounds)  
Girls, Age 11 Years

Narrow Chest										Medium Chest										Broad Chest										
Thoracic Lateral Width, 20.2 Cm. and Below					Thoracic Lateral Width, 20.3 to 23.7 Cm.					Thoracic Lateral Width, 23.8 Cm. and Above																				
Hgt. in Ins.					Hgt. in Ins.					Hgt. in Ins.					Width of Bi-iliac Diameter in Centimeters					Width of Bi-iliac Diameter in Centimeters					Width of Bi-iliac Diameter in Centimeters					
19.6 20.9 21.6 22.4 23.1 23.8 24.6 25.4 26.7					19.6 20.9 21.6 22.4 23.1 23.8 24.6 25.4 26.7					19.6 20.9 21.6 22.4 23.1 23.8 24.6 25.4 26.7					19.6 20.9 21.6 22.4 23.1 23.8 24.6 25.4 26.7					19.6 20.9 21.6 22.4 23.1 23.8 24.6 25.4 26.7										
48	47	52	54	57	59	61	64	67	71	48	57	61	64	67	69	71	74	75	76	81	48	66	70	73	76	78	80	83	86	90
49	49	53	55	59	61	63	66	68	73	49	58	63	65	68	70	72	75	78	82	82	49	68	72	74	77	79	81	84	87	92
50	50	55	57	60	62	65	67	70	74	50	60	64	67	70	72	74	77	80	84	84	50	69	74	76	79	81	83	86	89	93
51	52	56	59	62	64	66	69	71	76	51	62	66	68	71	73	75	78	81	85	85	51	71	75	77	80	82	84	88	90	95
52	53	58	60	63	65	67	70	73	77	52	63	67	70	73	75	77	80	83	87	87	52	72	77	79	82	84	86	89	92	96
53	55	59	62	65	67	69	72	74	79	53	65	69	71	74	76	78	81	84	89	89	53	74	78	81	84	86	88	91	93	98
54	56	61	63	66	68	70	73	76	80	54	66	71	73	76	78	80	83	86	90	90	54	75	80	82	85	87	89	92	95	99
55	58	62	65	68	70	72	75	78	82	55	68	72	74	77	79	81	85	87	92	92	55	77	81	84	87	89	91	94	96	101
56	60	64	66	69	71	73	76	79	83	56	69	74	76	79	81	83	86	89	93	93	56	78	83	85	88	90	92	95	98	102
57	61	65	68	71	73	75	78	81	85	57	71	75	78	81	83	85	88	90	95	95	57	80	84	87	90	92	94	97	100	104
58	63	67	69	72	74	76	80	82	87	58	72	77	79	82	84	86	89	92	96	96	58	82	86	88	91	93	95	98	101	105
59	64	69	71	74	76	78	81	84	88	59	74	78	81	84	86	88	91	93	98	98	59	83	87	90	93	95	97	100	103	107
60	66	70	72	75	78	80	83	85	90	60	75	80	82	85	87	89	92	95	99	99	60	85	89	91	94	96	98	101	104	109
61	67	72	74	77	79	81	84	87	91	61	77	81	84	87	89	91	94	97	101	101	61	86	91	93	96	98	100	103	106	110
62	69	73	76	79	81	83	86	88	93	62	79	83	85	88	90	92	95	98	102	102	62	88	92	94	97	99	101	105	107	112

TABLE 319—*Continued*  
 WIDTH-WEIGHT TABLES (Weight in Pounds)  
 Boys, Age 12 Years

Narrow Chest										Medium Chest										Broad Chest																		
Thoracic Lateral Width, 20.8 Cm. and Below										Thoracic Lateral Width, 20.9 to 22.7 Cm.										Thoracic Lateral Width, 22.8 Cm. and Above																		
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters																	
	18.8	20.2	21.1	22.1	23.1	24.1	25.1	26.0	27.4		18.8	20.2	21.1	22.1	23.1	24.1	25.1	26.0	27.4		18.8	20.2	21.1	22.1	23.1	24.1	25.1	26.0	27.4									
50	47	54	58	62	67	72	77	81	87	50	55	61	65	70	75	80	84	88	95	50	62	69	73	77	82	87	92	96	103	62	69	73	77	82	87	92	96	103
51	48	55	59	64	69	74	78	82	89	51	56	62	66	71	76	81	85	89	96	51	63	70	74	79	84	89	93	97	104	63	70	74	79	84	89	93	97	104
52	50	56	60	65	70	75	79	83	90	52	57	63	68	72	77	82	86	91	97	52	65	71	75	80	85	90	94	98	105	65	71	75	80	85	90	94	98	105
53	51	57	62	66	71	76	80	84	91	53	58	65	69	73	78	83	88	92	98	53	66	72	77	81	86	91	95	100	106	66	72	77	81	86	91	95	100	106
54	52	58	63	67	72	77	81	86	92	54	59	66	70	74	79	84	89	93	100	54	67	74	78	82	87	92	97	101	107	67	74	78	82	87	92	97	101	107
55	53	60	64	68	73	78	83	87	93	55	60	67	71	76	81	86	90	94	101	55	68	75	79	83	88	93	98	102	109	68	75	79	83	88	93	98	102	109
56	54	61	65	69	74	79	84	88	95	56	62	68	72	77	82	87	91	95	102	56	69	76	80	85	90	95	99	103	110	69	76	80	85	90	95	99	103	110
57	55	62	66	71	76	81	85	89	96	57	63	69	74	78	83	88	92	97	103	57	71	77	81	86	91	96	100	104	111	71	77	81	86	91	96	100	104	111
58	57	63	67	72	77	82	86	90	97	58	64	71	75	79	84	89	94	98	104	58	72	78	83	87	92	97	101	106	112	72	78	83	87	92	97	101	106	112
59	58	64	69	73	78	83	87	92	98	59	65	72	76	80	85	90	95	99	106	59	73	80	84	88	93	98	103	107	113	73	80	84	88	93	98	103	107	113
60	59	66	70	74	79	84	89	93	99	60	66	73	77	82	87	92	96	100	107	60	74	81	85	89	94	99	104	108	114	74	81	85	89	94	99	104	108	114
61	60	67	71	75	80	85	90	94	101	61	68	74	78	83	88	93	97	101	108	61	75	82	86	91	96	101	105	109	116	75	82	86	91	96	101	105	109	116
62	61	68	72	77	82	87	91	95	102	62	69	75	80	84	89	94	98	103	109	62	77	83	87	92	97	102	106	110	117	77	83	87	92	97	102	106	110	117
63	63	69	73	78	83	88	92	96	103	63	70	77	81	85	90	95	100	104	110	63	78	84	89	93	98	103	107	111	118	78	84	89	93	98	103	107	111	118
64	64	70	75	79	84	89	93	98	104	64	71	78	82	86	91	96	101	105	111	64	79	85	90	94	99	104	108	113	119	79	85	90	94	99	104	108	113	119
65	65	72	76	80	85	90	95	99	105	65	72	79	83	88	93	98	102	106	113	65	80	87	91	95	100	105	110	114	120	80	87	91	95	100	105	110	114	120

TABLE 319—Continued

## WIDTH-WEIGHT TABLES (Weight in Pounds)

Girls, Age 12 Years

Narrow Chest										Medium Chest										Broad Chest																		
Thoracic Lateral Width, 21.1 Cm. and Below										Thoracic Lateral Width, 21.2 to 25.0 Cm.										Thoracic Lateral Width, 25.1 Cm. and Above																		
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters																	
	20.6	21.6	22.3	23.2	24.1	25.0	25.9	26.6	27.6		20.6	21.6	22.3	23.2	24.1	25.0	25.9	26.6	27.6		20.6	21.6	22.3	23.2	24.1	25.0	25.9	26.6	27.6									
	49	52	54	57	60	63	66	68	71		50	61	64	66	69	72	75	78	80		84	50	75	78	80	83	86	89	92	94	98	75	78	80	83	86	89	92
50	50	54	56	59	62	65	68	70	73	51	63	66	68	71	74	77	80	82	85	51	77	80	82	85	88	91	94	96	99	77	80	82	85	88	91	94	96	99
52	52	55	58	61	64	67	69	72	75	52	64	68	70	73	76	79	82	84	87	52	78	82	84	87	90	93	96	98	101	78	82	84	87	90	93	96	98	101
53	54	57	59	62	65	68	71	73	77	53	66	69	72	74	77	80	83	86	89	53	80	83	86	88	91	94	97	100	103	80	83	86	88	91	94	97	100	103
54	56	59	61	64	67	70	73	75	78	54	68	71	73	76	79	82	85	87	91	54	82	85	87	90	93	96	99	101	105	82	85	87	90	93	96	99	101	105
55	57	61	63	66	69	72	75	77	80	55	70	73	75	78	81	84	87	89	92	55	84	87	89	92	95	98	101	103	106	84	87	89	92	95	98	101	103	106
56	59	62	65	68	71	74	76	79	82	56	71	75	77	80	83	86	89	91	94	56	85	89	91	94	97	100	103	105	108	85	89	91	94	97	100	103	105	108
57	61	64	66	69	72	75	78	80	84	57	73	76	79	81	84	87	90	93	96	57	87	90	93	95	98	101	104	107	110	87	90	93	95	98	101	104	107	110
58	63	66	68	71	74	77	80	82	85	58	75	78	80	83	86	89	92	94	98	58	89	92	94	97	100	103	106	108	112	89	92	94	97	100	103	106	108	112
59	64	68	70	73	76	79	82	84	87	59	77	80	82	85	88	91	94	96	99	59	91	94	96	99	102	105	108	110	113	91	94	96	99	102	105	108	110	113
60	66	69	72	75	78	81	83	86	89	60	78	82	84	87	90	93	96	98	101	60	92	96	98	101	104	107	110	112	115	92	96	98	101	104	107	110	112	115
61	68	71	73	76	79	82	85	87	91	61	80	83	86	89	92	95	97	100	103	61	94	97	100	103	106	109	111	114	117	94	97	100	103	106	109	111	114	117
62	70	73	75	78	81	84	87	89	92	62	82	85	87	90	93	96	99	101	105	62	96	99	101	104	107	110	113	115	119	96	99	101	104	107	110	113	115	119
63	71	75	77	80	83	86	89	91	94	63	84	87	89	92	95	98	101	103	106	63	98	101	103	106	109	112	115	117	120	98	101	103	106	109	112	115	117	120
64	73	76	79	82	85	88	90	93	96	64	85	89	91	94	97	100	103	105	108	64	99	103	105	108	111	114	117	119	122	99	103	105	108	111	114	117	119	122
65	75	78	80	83	86	89	92	95	98	65	87	90	93	96	99	101	104	107	110	65	101	104	107	110	113	116	118	121	124	101	104	107	110	113	116	118	121	124

TABLE 319—Continued  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Boys, Age 13 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 21.8 Cm. and Below										Thoracic Lateral Width, 21.9 to 25.1 Cm.										Thoracic Lateral Width, 25.2 Cm. and Above									
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters								
19.2	20.7	21.6	22.6	23.6	24.6	25.6	26.5	28.0		19.2	20.7	21.6	22.6	23.6	24.6	25.6	26.5	28.0		19.2	20.7	21.6	22.6	23.6	24.6	25.6	26.5	28.0	
52	57	61	64	67	70	73	76	79	84	52	67	72	74	77	80	83	87	89	94	52	77	82	84	87	90	93	97	99	
53	58	63	66	69	72	75	78	81	85	53	69	73	76	79	82	85	88	91	96	53	79	83	86	89	92	95	98	101	
54	60	65	68	71	74	77	80	83	87	54	71	75	78	81	84	87	90	93	98	54	81	85	88	91	94	97	100	103	
55	62	67	69	73	76	79	82	84	89	55	72	77	80	83	86	89	92	95	99	55	82	87	90	93	96	99	102	105	
56	64	68	71	74	77	80	84	86	91	56	74	79	82	85	88	91	94	97	101	56	84	89	92	95	98	101	104	107	
57	66	70	73	76	79	82	85	88	93	57	76	81	84	87	90	93	96	99	103	57	86	91	94	97	100	103	106	109	
58	68	72	75	78	81	84	87	90	95	58	78	83	85	88	91	94	98	100	105	58	88	93	95	98	101	104	108	110	
59	69	74	77	80	83	86	89	92	96	59	80	84	87	90	93	96	99	102	107	59	90	94	97	100	103	106	109	112	
60	71	76	79	82	85	88	91	94	98	60	82	86	89	92	95	98	101	104	109	60	92	96	99	102	105	108	111	114	
61	73	77	80	84	87	90	93	95	100	61	83	88	91	94	97	100	103	106	110	61	93	98	101	104	107	110	113	116	
62	75	79	82	85	88	91	94	97	102	62	85	90	93	96	99	102	105	108	112	62	95	100	103	106	109	112	115	118	
63	77	81	84	87	90	93	96	99	104	63	87	92	94	98	101	104	107	110	114	63	97	102	104	108	111	114	117	120	
64	79	83	86	89	92	95	98	101	106	64	89	94	96	99	102	105	109	111	116	64	99	104	106	109	112	115	119	121	
65	80	85	88	91	94	97	100	103	107	65	91	95	98	101	104	107	110	113	118	65	101	105	108	111	114	117	120	123	
66	82	87	90	93	96	99	102	105	109	66	93	97	100	103	106	109	112	115	120	66	103	107	110	113	116	119	122	125	
67	84	89	91	94	97	100	104	106	111	67	94	99	102	105	108	111	114	117	121	67	104	109	112	115	118	121	124	127	

TABLE 319—*Continued*  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Girls, Age 13 Years

Narrow Chest										Medium Chest										Broad Chest												
Hgt. in Ins.		Thoracic Lateral Width, 21.3 Cm. and Below									Hgt. in Ins.		Thoracic Lateral Width, 21.4 to 25.0 Cm.									Hgt. in Ins.		Thoracic Lateral Width, 25.1 Cm. and Above								
		Width of Bi-iliac Diameter in Centimeters											Width of Bi-iliac Diameter in Centimeters											Width of Bi-iliac Diameter in Centimeters								
		21.0	22.9	23.8	24.7	25.6	26.5	27.4	28.3	29.2			21.0	22.9	23.8	24.7	25.6	26.5	27.4	28.3	29.2			21.0	22.9	23.8	24.7	25.6	26.5	27.4	28.3	29.2
53		62	65	68	71	74	77	80	83	86	53	74	77	80	83	86	89	92	95	98	53	76	79	82	85	88	91	94	97	100	103	
54		63	66	69	72	75	78	81	84	87	54	75	78	81	84	87	90	93	96	99	54	77	80	83	86	89	92	95	98	101	104	
55		64	67	70	73	76	79	82	85	88	55	76	79	82	85	88	91	94	97	100	55	78	81	84	87	90	93	96	99	102	105	
56		65	68	71	74	77	80	83	86	89	56	77	80	83	86	89	92	95	98	101	56	79	82	85	88	91	94	97	100	103	106	
57		66	69	72	75	78	81	84	87	90	57	78	81	84	87	90	93	96	99	102	57	80	83	86	89	92	95	98	101	104	107	
58		67	70	73	76	79	82	85	88	91	58	79	82	85	88	91	94	97	100	103	58	81	84	87	90	93	96	99	102	105	108	
59		69	72	75	78	81	84	87	90	93	59	81	84	87	90	93	96	99	102	105	59	83	86	89	92	95	98	101	104	107	110	
60		70	73	76	79	82	85	88	91	94	60	82	85	88	91	94	97	100	103	106	60	84	87	90	93	96	99	102	105	108	111	
61		72	75	78	81	84	87	90	93	96	61	84	87	90	93	96	99	102	105	108	61	86	89	92	95	98	101	104	107	110	113	
62		73	76	79	82	85	88	91	94	97	62	85	88	91	94	97	100	103	106	109	62	87	90	93	96	99	102	105	108	111	114	
63		75	78	81	84	87	90	93	96	99	63	87	90	93	96	99	102	105	108	111	63	89	92	95	98	101	104	107	110	113	116	
64		76	79	82	85	88	91	94	97	100	64	88	91	94	97	100	103	106	109	112	64	90	93	96	99	102	105	108	111	114	117	
65		78	81	84	87	90	93	96	99	102	65	90	93	96	99	102	105	108	111	114	65	92	95	98	101	104	107	110	113	116	119	
66		79	82	85	88	91	94	97	100	103	66	91	94	97	100	103	106	109	112	115	66	93	96	99	102	105	108	111	114	117	120	
67		81	84	87	90	93	96	99	102	105	67	93	96	99	102	105	108	111	114	117	67	95	98	101	104	107	110	113	116	119	122	
68		82	86	89	91	94	97	100	103	106	68	94	97	100	103	106	109	112	115	118	68	96	99	102	105	108	111	114	117	120	123	

TABLE 319—Continued

WIDTH-WEIGHT TABLES (Weight in Pounds)

Boys, Age 14 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 23.5 Cm. and Below										Thoracic Lateral Width, 23.6 to 26.6 Cm.										Thoracic Lateral Width, 26.7 Cm. and Above									
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters								
	20.3	21.8	22.7	23.8	24.9	26.0	27.1	28.0	29.5		20.3	21.8	22.7	23.8	24.9	26.0	27.1	28.0	29.5		20.3	21.8	22.7	23.8	24.9	26.0	27.1	28.0	29.5
54	67	72	75	78	82	86	89	92	97	54	80	85	88	91	95	99	102	105	110	54	95	100	102	106	110	114	117	120	125
55	69	74	77	80	84	88	91	94	99	55	82	87	90	93	97	101	104	107	112	55	97	101	104	108	112	116	119	122	127
56	71	76	79	82	86	90	93	96	101	56	84	89	92	95	99	103	106	109	114	56	99	103	106	110	114	118	121	124	129
57	73	78	81	84	88	92	95	98	103	57	86	91	94	97	101	105	108	111	116	57	100	105	108	111	115	119	123	126	130
58	75	80	83	86	90	94	97	100	105	58	88	93	96	99	103	107	110	113	118	58	102	107	110	113	117	121	125	127	132
59	77	82	85	88	92	96	99	102	107	59	90	95	98	101	105	109	112	115	120	59	104	109	112	115	119	123	126	129	134
60	79	84	87	90	94	98	101	104	109	60	92	97	100	103	107	111	114	117	122	60	106	111	114	117	121	125	128	131	136
61	81	86	89	92	96	100	103	106	111	61	94	99	102	105	109	113	116	119	124	61	108	113	116	119	123	127	130	133	138
62	83	88	91	94	98	102	105	108	113	62	96	101	104	107	111	115	118	121	126	62	110	115	118	121	125	129	132	135	140
63	85	90	92	96	100	104	107	110	115	63	98	103	106	109	113	117	120	123	128	63	112	117	120	123	127	131	134	137	142
64	87	91	94	98	102	106	109	112	117	64	100	105	107	111	115	119	122	125	130	64	114	119	122	125	129	133	136	139	144
65	89	93	96	100	104	108	111	114	119	65	102	106	109	113	117	121	124	127	132	65	116	121	124	127	131	135	138	141	146
66	90	95	98	101	105	109	113	116	120	66	104	108	111	115	119	123	126	129	134	66	118	123	126	129	133	137	140	143	148
67	92	97	100	103	107	111	115	118	122	67	105	110	113	116	120	124	128	131	135	67	120	125	128	131	135	139	142	145	150
68	94	99	102	105	109	113	117	119	124	68	107	112	115	118	122	126	130	132	137	68	122	127	130	133	137	141	144	147	152
69	96	101	104	107	111	115	118	121	126	69	109	114	117	120	124	128	131	134	139	69	124	129	131	135	139	143	146	149	154
70	98	103	106	109	113	117	120	123	128	70	111	116	119	122	126	130	133	136	141	70	126	130	133	137	141	145	148	151	156
71	100	105	108	111	115	119	122	125	130	71	113	118	121	124	128	132	135	138	143	71	128	132	135	139	143	148	150	153	158

TABLE 319—Continued

WIDTH-WEIGHT TABLES (Weight in Pounds)  
Girls, Age 14 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 21.8 Cm. and Below										Thoracic Lateral Width, 21.9 to 24.8 Cm.										Thoracic Lateral Width, 24.9 Cm. and Above									
Hgt. in Ins.		Width of Bi-iliac Diameter in Centimeters								Hgt. in Ins.		Width of Bi-iliac Diameter in Centimeters								Hgt. in Ins.		Width of Bi-iliac Diameter in Centimeters							
21.8	23.1	23.9	24.9	25.5	26.7	27.3	28.1	29.4		21.8	23.1	23.9	24.9	25.8	26.7	27.3	28.1	29.4		21.8	23.1	23.9	24.9	25.8	26.7	27.3	28.1	29.4	
55	72	77	80	84	87	90	92	95	100	55	84	89	92	96	99	102	104	107	112	55	97	101	104	108	111	114	117	120	125
56	73	78	81	85	88	91	94	97	102	56	85	90	93	97	100	103	106	109	113	56	98	103	106	109	112	115	118	121	126
57	74	79	82	86	89	92	95	98	103	57	86	91	94	98	101	104	107	110	115	57	99	104	107	110	113	116	120	123	128
58	75	81	84	88	91	94	96	99	104	58	88	93	96	100	103	106	108	111	116	58	100	105	108	111	114	117	121	124	129
59	77	82	85	89	92	95	98	101	105	59	89	94	97	101	104	107	109	112	117	59	102	107	110	113	116	119	122	125	130
60	78	83	86	90	93	96	99	102	107	60	90	95	98	102	105	108	111	114	119	60	103	108	111	114	117	120	124	127	131
61	80	84	87	92	95	98	100	103	108	61	92	96	99	103	106	109	112	115	120	61	104	109	112	115	118	121	125	128	133
62	81	86	89	93	96	99	101	104	109	62	93	98	101	105	103	111	113	116	121	62	106	110	113	117	120	123	126	129	134
63	82	87	90	94	97	100	103	106	111	63	94	99	102	106	109	112	115	118	122	63	107	112	115	118	121	124	127	130	135
64	83	88	91	95	98	101	104	107	112	64	95	100	103	107	110	113	116	119	124	64	108	113	116	119	122	125	129	132	137
65	85	90	93	97	100	103	105	108	113	65	97	102	104	109	112	115	117	120	125	65	109	114	117	120	123	126	130	133	138
66	86	91	94	98	101	104	107	110	114	66	98	103	106	110	113	116	118	121	126	66	111	116	119	122	125	128	131	134	139
67	87	92	95	99	102	105	108	111	116	67	99	104	107	111	114	117	120	123	128	67	112	117	120	123	126	129	133	136	140
68	89	93	96	101	104	107	109	112	117	68	100	105	108	112	115	118	121	124	129	68	113	118	121	124	127	130	134	137	142
69	90	95	98	102	105	108	110	113	118	69	102	107	110	113	117	120	122	125	130	69	115	119	122	126	129	132	135	138	143
70	91	96	99	103	106	109	112	115	120	70	103	108	111	115	118	121	124	127	131	70	116	121	124	127	130	133	136	139	144
71	92	97	100	104	107	110	113	116	121	71	104	109	112	116	119	122	125	128	133	71	117	122	125	128	131	134	138	141	146

WIDTH-WEIGHT TABLES (Weight in Pounds)  
Boys, Age 15 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 23.3 Cm. and Below										Thoracic Lateral Width, 23.4 to 27.2 Cm.										Thoracic Lateral Width, 27.3 Cm. and Above									
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters								
	20.7	22.2	23.2	24.3	25.4	26.5	27.6	28.6	30.1		20.7	22.2	23.2	24.3	25.4	26.5	27.6	28.6	30.1		20.7	22.2	23.2	24.3	25.4	26.5	27.6	28.6	30.1
56	68	71	74	76	79	82	85	87	91	56	84	88	90	93	96	99	101	104	107	56	102	106	109	111	114	117	120	122	126
57	70	74	77	79	82	85	87	90	94	57	87	90	93	95	98	101	104	106	110	57	105	109	111	114	117	120	122	125	129
58	73	77	79	82	85	88	90	93	96	58	89	93	96	98	101	104	107	109	113	58	108	112	114	117	120	123	125	128	131
59	76	80	82	85	88	91	93	95	99	59	92	96	98	101	104	107	109	112	116	59	111	114	117	119	122	125	128	130	134
60	79	82	85	88	90	93	96	98	102	60	95	99	101	104	107	110	112	115	118	60	113	117	120	122	125	128	131	133	137
61	81	85	88	90	93	96	99	101	105	61	98	101	104	106	109	112	115	117	121	61	116	120	122	125	128	131	133	136	140
62	84	88	90	93	96	99	101	104	107	62	101	104	107	109	112	115	118	120	124	62	119	123	125	128	131	134	136	139	142
63	87	91	93	96	99	102	104	106	110	63	103	107	109	112	115	118	120	123	127	63	122	125	128	130	133	136	139	141	145
64	90	93	96	99	101	104	107	109	113	64	106	110	112	115	118	121	123	126	129	64	125	128	131	133	136	139	142	144	148
65	92	96	99	101	104	107	110	112	116	65	109	112	115	117	120	123	126	128	132	65	127	131	133	136	139	142	144	147	151
66	95	99	101	104	107	110	112	115	118	66	112	115	118	120	123	126	129	131	135	66	130	134	136	139	142	145	147	150	153
67	98	102	104	107	110	113	115	118	121	67	114	118	120	123	126	129	131	134	138	67	133	136	139	141	144	147	150	152	156
68	101	104	107	109	112	115	118	120	124	68	117	121	123	126	129	132	134	137	140	68	136	139	142	144	147	150	153	155	159
69	103	107	110	112	115	118	121	123	127	69	120	124	126	128	131	134	137	139	143	69	138	142	144	147	150	153	155	158	162
70	106	110	112	115	118	121	123	126	129	70	123	126	129	131	134	137	140	142	146	70	141	145	147	150	153	156	158	161	164
71	109	113	115	118	121	124	126	129	132	71	125	129	131	134	137	140	142	145	149	71	144	148	150	152	155	158	161	163	167
72	112	115	118	120	123	126	129	131	135	72	128	132	134	137	140	143	145	148	151	72	147	150	153	155	158	161	164	166	170
73	114	118	121	123	126	129	132	134	138	73	131	135	137	139	142	145	148	150	154	73	149	153	155	158	161	164	166	169	173
74	117	121	123	126	129	132	134	137	141	74	134	137	140	142	145	148	151	153	157	74	152	156	158	161	164	167	169	172	175

TABLE 319—Continued  
WIDTH-WEIGHT TABLES (Weight in Pounds)  
Girls, Age 15 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 22.2 Cm. and Below										Thoracic Lateral Width, 22.3 to 25.1 Cm.										Thoracic Lateral Width, 25.2 Cm. and Above									
Hgt. in Ins.										Hgt. in Ins.										Width of Bi-iliac Diameter in Centimeters									
Width of Bi-iliac Diameter in Centimeters										Width of Bi-iliac Diameter in Centimeters										Width of Bi-iliac Diameter in Centimeters									
22.3	23.4	24.5	25.4	26.2	27.0	27.9	29.0	30.1	22.3	23.4	24.5	25.4	26.2	27.0	27.9	29.0	30.1	22.3	23.4	24.5	25.4	26.2	27.0	27.9	29.0	30.1			
78	81	85	88	91	94	97	101	105	57	89	92	96	99	102	105	108	112	116	57	99	103	107	110	113	116	119	123	127	
79	82	86	89	92	95	98	102	106	58	90	93	97	100	103	106	109	113	117	58	100	104	108	111	114	117	120	124	128	
81	84	88	91	94	97	100	104	108	59	92	95	99	102	105	108	111	115	119	59	102	106	110	113	116	119	122	126	130	
83	86	90	93	96	99	102	106	110	60	94	97	101	104	107	110	113	117	121	60	104	108	112	115	118	121	124	128	132	
85	88	92	95	98	101	104	108	112	61	95	99	103	106	109	112	115	119	123	61	106	110	114	117	120	123	126	130	134	
87	90	94	97	100	103	106	110	114	62	97	101	105	108	111	114	117	121	125	62	108	112	116	119	122	125	128	132	136	
88	91	95	98	101	104	107	111	115	63	98	102	106	109	112	115	118	122	126	63	109	113	117	120	123	126	129	133	137	
89	92	96	99	102	105	108	112	116	64	99	103	107	110	113	116	119	123	127	64	110	114	118	121	124	127	130	134	138	
90	93	97	100	103	106	109	113	117	65	100	104	108	111	114	117	120	124	128	65	111	115	119	122	125	128	131	135	139	
92	95	99	102	105	108	111	115	119	66	102	106	110	113	116	119	122	126	130	66	113	117	121	124	127	130	133	137	141	
93	96	100	103	106	109	112	116	120	67	103	107	111	114	117	120	123	127	131	67	114	118	122	125	128	131	134	138	142	
94	97	101	104	107	110	113	117	121	68	104	108	112	115	118	121	124	128	132	68	115	119	123	126	129	132	135	139	143	
96	99	103	106	109	112	115	119	123	69	106	110	114	117	120	123	126	130	134	69	117	121	125	128	131	134	137	141	145	
97	100	104	107	110	113	116	120	124	70	107	111	115	118	121	124	127	131	135	70	118	122	126	129	132	135	138	142	146	
98	101	105	108	111	114	117	121	125	71	108	112	116	119	122	125	128	132	136	71	119	123	127	130	133	136	139	143	147	

TABLE 319—Continued

## WIDTH-WEIGHT TABLES (Weight in Pounds)

Boys, Age 16 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 25.1 Cm. and Below										Thoracic Lateral Width, 25.2 to 28.6 Cm.										Thoracic Lateral Width, 28.7 Cm. and Above									
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters								
20.6	22.5	23.6	24.9	26.2	27.5	28.8	29.9	31.1		20.6	22.5	23.6	24.9	26.2	27.5	28.8	29.9	31.1		20.6	22.5	23.6	24.9	26.2	27.5	28.8	29.9	31.1	
59	86	90	92	95	98	101	104	106	110	59	100	104	106	109	112	115	118	120	124	59	116	120	122	125	128	131	134	136	140
60	90	93	95	98	101	104	107	109	113	60	103	107	109	112	115	118	121	123	127	60	119	123	125	128	131	134	137	139	143
61	93	96	98	101	104	107	110	112	116	61	106	110	112	115	118	121	124	126	130	61	122	126	128	131	134	137	140	142	146
62	96	99	101	104	107	110	113	115	119	62	109	113	115	118	121	124	127	129	133	62	125	129	131	134	137	140	143	145	149
63	99	101	104	107	110	113	116	118	122	63	112	116	118	121	124	127	130	132	136	63	128	132	134	137	140	143	146	148	152
64	101	104	107	111	113	116	119	121	125	64	115	119	121	124	127	130	133	135	139	64	131	135	137	140	143	146	149	151	155
65	104	107	110	113	116	119	122	124	128	65	118	121	124	127	130	133	136	138	142	65	134	138	140	143	146	149	152	154	158
66	107	110	113	116	119	122	125	127	131	66	121	124	127	130	133	136	139	141	145	66	137	141	143	146	149	152	155	157	161
67	110	113	116	119	121	124	128	130	134	67	124	127	130	133	136	139	142	144	148	67	140	144	146	149	152	155	158	160	164
68	113	116	119	122	124	127	131	133	137	68	127	130	133	136	139	142	145	147	151	68	143	147	149	152	155	158	161	163	167
69	116	119	121	124	127	130	134	136	139	69	130	133	136	139	142	145	148	150	154	69	146	150	152	155	158	161	164	166	170
70	119	121	124	127	130	133	137	139	141	70	132	136	139	142	145	148	151	153	157	70	149	153	155	158	161	164	167	169	173
71	121	123	126	129	132	135	139	141	143	71	134	138	141	144	147	150	153	155	159	71	152	156	158	161	164	167	170	172	176
72	123	125	128	131	134	137	141	143	145	72	136	140	143	146	149	152	155	157	161	72	155	159	161	164	167	170	173	175	179
73	125	128	131	134	137	140	143	145	148	73	139	143	146	149	152	155	158	160	164	73	158	162	164	167	170	173	176	178	182
74	127	131	133	136	139	142	145	147	151	74	141	145	148	152	155	158	160	162	166	74	161	165	167	170	173	176	179	181	185

TABLE 319—*Continued*

WIDTH-WEIGHT TABLES (Weight in Pounds)

Girls, Age 16 Years

Narrow Chest										Medium Chest										Broad Chest									
Thoracic Lateral Width, 22.7 Cm. and Below										Thoracic Lateral Width, 22.8 to 25.8 Cm.										Thoracic Lateral Width, 25.9 Cm. and Above									
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters								
	22.9	24.1	24.9	25.7	26.6	27.5	28.4	29.2	30.5		22.9	24.1	24.9	25.7	26.6	27.5	28.4	29.2	30.5		22.9	24.1	24.9	25.7	26.6	27.5	28.4	29.2	30.5
58	86	89	92	93	96	99	102	104	108	58	93	97	99	101	104	107	109	111	115	58	106	111	113	115	118	120	123	125	129
59	87	90	93	95	98	101	103	105	109	59	94	98	100	102	105	108	110	112	116	59	107	112	114	116	119	121	124	126	130
60	88	92	94	96	99	102	104	106	110	60	96	100	102	104	107	110	112	114	118	60	108	113	115	117	120	122	125	127	131
61	89	93	95	97	100	103	105	107	111	61	98	102	104	106	109	112	114	116	120	61	109	114	116	118	121	123	126	128	132
62	90	94	96	98	101	104	106	108	112	62	99	103	105	107	110	113	115	117	121	62	110	115	117	119	122	124	127	129	133
63	92	95	97	99	102	105	107	109	113	63	101	105	107	109	112	115	117	119	123	63	112	117	119	121	124	126	129	131	134
64	93	96	98	100	103	106	108	111	114	64	103	107	109	111	114	117	119	121	125	64	113	118	120	122	125	127	130	132	136
65	94	97	100	101	104	107	109	112	115	65	105	109	111	113	116	119	121	123	127	65	114	119	121	123	126	128	131	133	137
66	95	98	101	102	105	108	111	113	117	66	106	110	112	114	117	120	122	124	128	66	115	120	122	124	127	129	132	134	138
67	96	99	102	104	107	110	112	114	118	67	108	112	114	116	119	122	124	126	130	67	116	121	123	125	128	130	133	135	139
68	97	101	103	105	108	111	113	115	119	68	110	114	116	118	121	124	125	127	131	68	117	122	124	126	129	131	134	136	140
69	98	102	104	106	109	112	114	116	120	69	111	115	117	119	122	125	127	129	133	69	118	123	125	127	130	132	135	137	141
70	99	103	105	107	110	113	115	117	121	70	113	117	119	121	124	127	129	131	135	70	120	125	127	129	132	134	137	139	143
71	101	104	106	108	111	114	116	119	122	71	115	119	121	123	126	129	131	133	137	71	121	126	128	130	133	135	138	140	144

TABLE 319—Continued

WIDTH-WEIGHT TABLES (Weight in Pounds)

Boys, Age 17 Years

<i>Narrow Chest</i>										<i>Medium Chest</i>										<i>Broad Chest</i>									
Thoracic Lateral Width, 26.0 Cm. and Below										Thoracic Lateral Width, 26.1 to 29.2 Cm.										Thoracic Lateral Width, 29.3 Cm. and Above									
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters									Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters								
	21.9	23.4	24.5	25.3	27.2	29.1	29.9	31.0	32.5		21.9	23.4	24.5	25.3	27.2	29.1	29.9	31.0	32.5		21.9	23.4	24.5	25.3	27.2	29.1	29.9	31.0	32.5
61	108	113	114	115	118	121	122	124	128	61	117	122	123	125	127	130	131	133	137	61	127	131	133	134	137	140	141	143	147
62	110	114	116	116	120	123	124	126	130	62	119	124	125	126	129	132	133	135	139	62	129	133	135	136	139	142	143	144	149
63	112	116	118	118	122	125	126	128	132	63	121	125	127	128	131	134	135	137	141	63	131	135	137	138	141	143	145	146	151
64	114	118	120	120	124	127	128	130	134	64	123	127	129	130	133	136	137	139	143	64	133	137	139	140	143	146	147	149	153
65	116	120	122	122	126	130	130	132	136	65	125	129	131	132	135	138	139	141	145	65	136	140	142	143	146	149	150	152	156
66	118	122	124	124	128	131	132	133	138	66	127	131	133	134	137	140	141	143	147	66	139	143	145	146	149	152	153	155	159
67	120	124	126	126	130	133	134	135	140	67	130	134	136	137	140	143	144	146	150	67	142	146	148	149	152	155	156	158	162
68	122	126	127	128	132	134	136	137	142	68	133	137	139	140	143	146	147	149	153	68	145	149	151	152	155	158	159	161	165
69	123	128	129	130	133	136	137	139	143	69	136	140	142	143	146	149	150	152	156	69	148	152	154	155	158	161	162	164	168
70	125	130	131	132	135	138	139	141	145	70	139	143	145	146	149	152	153	155	159	70	151	155	157	158	161	164	165	167	171
71	127	132	133	134	137	140	141	143	147	71	142	146	148	149	152	155	156	158	162	71	154	158	160	161	164	167	168	170	174
72	129	133	135	135	139	142	143	145	149	72	145	149	151	152	155	158	159	161	165	72	157	161	163	164	167	170	171	173	177
73	131	135	137	137	141	144	145	147	151	73	148	152	154	155	158	161	162	164	168	73	160	164	166	167	170	173	174	176	180
74	133	137	139	139	143	146	147	150	153	74	151	155	157	158	161	164	165	167	171	74	163	167	169	170	173	176	177	179	183

TABLE 319--Continued

WIDTH-WEIGHT TABLES (Weight in Pounds)

Girls, Age 17 Years

Narrow Chest				Medium Chest				Broad Chest											
Thoracic Lateral Width, 23.4 Cm. and Below		Thoracic Lateral Width, 23.5 to 25.3 Cm.		Thoracic Lateral Width, 25.4 Cm. and Above															
Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters	Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters	Hgt. in Ins.	Width of Bi-iliac Diameter in Centimeters	Width of Bi-iliac Diameter in Centimeters		Width of Bi-iliac Diameter in Centimeters		Width of Bi-iliac Diameter in Centimeters									
22.6	24.1	25.1	25.8	27.4	29.0	29.7	30.7	32.2	22.6	24.1	25.1	25.8	27.4	29.0	29.7	30.7	32.2		
59	86	91	94	96	101	106	108	111	116	59	108	113	116	119	124	129	131	134	139
60	87	92	95	97	102	107	110	113	118	60	110	115	118	120	125	130	132	135	140
61	89	94	97	99	104	109	111	114	119	61	112	117	120	122	127	132	134	137	142
62	91	96	99	101	106	111	113	116	121	62	113	118	122	124	129	134	136	139	144
63	92	97	100	103	108	113	115	118	123	63	115	120	123	125	130	135	138	141	146
64	94	99	102	104	109	114	116	119	124	64	117	122	125	127	132	137	139	142	147
65	96	101	104	106	111	116	118	121	126	65	119	124	127	129	134	139	141	144	149
66	97	102	106	108	113	118	120	123	128	66	120	125	128	131	135	140	143	146	151
67	99	104	107	109	114	119	121	125	130	67	122	127	130	132	137	142	144	147	152
68	101	106	109	111	116	121	123	126	131	68	124	129	132	134	139	144	146	149	154
69	103	108	111	113	118	123	125	128	133	69	125	130	133	136	141	146	148	151	156
70	104	109	112	115	119	124	127	130	135	70	127	132	135	137	142	147	149	153	158
71	106	111	114	116	121	126	128	131	136	71	129	134	137	139	144	149	151	154	159

## STANDARDS FOR ADULTS

Determination of a single ideal weight standard for adults is actually impossible since many variable factors must be considered. The influence of skeletal proportions is reflected in the Ideal Weight Tables of the Metropolitan Life Insurance Company, which are based on the most favorable weights for longevity and apply to all persons of twenty-five years of age and over. These values are based on the inference that weight increment after thirty years of age unfavorably affects longevity.

Heretofore the most widely used standards for adults were those of the Medico-Actuarial Investigation<sup>1</sup> of 1912, which was based on data from large groups of persons accepted as insurance risks and therefore assumed to be healthy.

TABLE 320

IDEAL WEIGHT TABLES BASED ON MAXIMUM LONGEVITY  
(Metropolitan Life Insurance Company)<sup>4,5</sup>  
Men (Age 25 Years and Over)

Height (with Shoes)		Weight in Pounds (as Ordinarily Dressed)		
		Small Frame	Medium Frame	Large Frame
Feet	Inches			
5	2	116-125	124-133	131-142
5	3	119-128	127-136	133-144
5	4	122-132	130-140	137-149
5	5	126-136	134-144	141-153
5	6	129-139	137-147	145-157
5	7	133-143	141-151	149-162
5	8	136-147	145-156	153-166
5	9	140-151	149-160	157-170
5	10	144-155	153-164	161-175
5	11	148-159	157-168	165-180
6	0	152-164	161-173	169-185
6	1	157-169	166-178	174-190
6	2	163-175	171-184	179-196
6	3	168-180	176-189	184-202

Women (Age 25 Years and Over)

Height (with Shoes)		Weight in Pounds (as Ordinarily Dressed)		
		Small Frame	Medium Frame	Large Frame
Feet	Inches			
4	11	104-111	110-118	117-127
5	0	105-113	112-120	119-129
5	1	107-115	114-122	121-131
5	2	110-118	117-125	124-135
5	3	113-121	120-128	127-138
5	4	116-125	124-132	131-142
5	5	119-128	127-135	133-145
5	6	123-132	130-140	138-150
5	7	126-136	134-144	142-154
5	8	129-139	137-147	145-158
5	9	133-143	141-151	149-162
5	10	136-147	145-155	152-166
5	11	139-150	148-158	155-169
6	0	141-153	151-163	160-174

TABLE 321

HEIGHTS AND WEIGHTS OF 221,819 MEN 15 OR MORE YEARS OF AGE (WITH CLOTHES)  
(Actuarial Society of America, 1912)<sup>1</sup>

Graded Average Weight in Pounds with Clothes*																		
Age	Feet and Inches with Shoes*																	
	5-0	5-1	5-2	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11	6-0	6-1	6-2	6-3	6-4	6-5
15	107	109	112	115	118	122	126	130	134	138	142	147	152	157	162	167	172	177
16	109	111	114	117	120	124	128	132	136	140	144	149	154	159	164	169	174	179
17	111	113	116	119	122	126	130	134	138	142	146	151	156	161	166	171	176	181
18	113	115	118	121	124	128	132	136	140	144	148	153	158	163	168	173	178	183
19	115	117	120	123	126	130	134	138	142	146	150	155	160	165	170	175	180	185
20	117	119	122	125	128	132	136	140	144	148	152	156	161	166	171	176	181	186
21	118	120	123	126	130	134	138	141	145	149	153	157	162	167	172	177	182	187
22	119	121	124	127	131	135	139	142	146	150	154	158	163	168	173	178	183	188
23	120	122	125	128	132	136	140	143	147	151	155	159	164	169	175	180	185	190
24	121	123	126	129	133	137	141	144	148	152	156	160	165	171	177	182	187	192
25	122	124	126	129	133	137	141	145	149	153	157	162	167	173	179	184	189	194
26	123	125	127	130	134	138	142	146	150	154	158	163	168	174	180	186	191	196
27	124	126	128	131	134	138	142	146	150	154	158	163	169	175	181	187	192	197
28	125	127	129	132	135	139	143	147	151	155	159	164	170	176	182	188	193	198
29	126	128	130	133	136	140	144	148	152	156	160	165	171	177	183	189	194	199
30	126	128	130	133	136	140	144	148	152	156	161	166	172	178	184	190	196	201
31	127	129	131	134	137	141	145	149	153	157	162	167	173	179	185	191	197	202
32	127	129	131	134	137	141	145	149	154	158	163	168	174	180	186	192	198	203
33	127	129	131	134	137	141	145	149	154	159	164	169	175	181	187	193	199	204
34	128	130	132	135	138	142	146	150	155	160	165	170	176	182	188	194	200	206
35	128	130	132	135	138	142	146	150	155	160	165	170	176	182	189	195	201	207
36	129	131	133	136	139	143	147	151	156	161	166	171	177	183	190	196	202	208
37	129	131	133	136	140	144	148	152	157	162	167	172	178	184	191	197	203	209
38	130	132	134	137	140	144	148	152	157	162	167	173	179	185	192	198	204	210
39	130	132	134	137	140	144	148	152	157	162	167	173	179	185	192	199	205	211
40	131	133	135	138	141	145	149	153	158	163	168	174	180	186	193	200	206	212
41	131	133	135	138	141	145	149	153	158	163	168	174	180	186	193	200	207	213
42	132	134	136	139	142	146	150	154	159	164	169	175	181	187	194	201	208	214
43	132	134	136	139	142	146	150	154	159	164	169	175	181	187	194	201	208	214
44	133	135	137	140	143	147	151	155	160	165	170	176	182	188	195	202	209	215
45	133	135	137	140	143	147	151	155	160	165	170	176	182	188	195	202	209	215
46	134	136	138	141	144	148	152	156	161	166	171	177	183	189	196	203	210	216
47	134	136	138	141	144	148	152	156	161	167	171	177	183	190	197	204	211	217
48	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
49	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
50	134	136	138	141	144	148	152	156	161	166	171	177	183	190	197	204	211	217
51	135	137	139	142	145	149	153	157	162	167	172	178	184	191	198	205	212	218
52	135	137	139	142	145	149	153	157	162	167	172	178	184	191	198	205	212	218
53	135	137	139	142	145	149	153	157	162	167	172	178	184	191	198	205	212	218
54	135	137	139	142	145	149	153	158	163	168	173	178	184	191	198	205	212	219
55	135	137	139	142	145	149	153	158	163	168	173	178	184	191	198	205	212	219

\* Allow 1 inch for shoes and 10 pounds for clothes.

TABLE 322

HEIGHTS AND WEIGHTS OF 136,504 WOMEN 15 OR MORE YEARS OF AGE WITH CLOTHES  
(Actuarial Society of America, 1912)<sup>1</sup>

Age	Feet and Inches with Shoes*															
	4-8	4-9	4-10	4-11	5-0	5-1	5-2	5-3	5-4	5-5	5-6	5-7	5-8	5-9	5-10	5-11
15	101	103	105	106	107	109	112	115	118	122	126	130	134	138	142	147
16	102	104	106	108	109	111	114	117	120	124	128	132	136	139	143	148
17	103	105	107	109	111	113	116	119	122	125	129	133	137	140	144	149
18	104	106	108	110	112	114	117	120	123	126	130	134	138	141	145	150
19	105	107	109	111	113	115	118	121	124	127	131	135	139	142	146	151
20	106	108	110	112	114	116	119	122	125	128	132	136	140	143	147	151
21	107	109	111	113	115	117	120	123	126	129	133	137	141	144	148	152
22	107	109	111	113	115	117	120	123	126	129	133	137	141	145	149	153
23	108	110	112	114	116	118	121	124	127	130	134	138	142	146	150	153
24	109	111	113	115	117	119	121	124	127	130	134	138	142	146	150	154
25	109	111	113	115	117	119	121	124	128	131	135	139	143	147	151	154
26	110	112	114	116	118	120	122	125	128	131	135	139	143	147	151	155
27	110	112	114	116	118	120	122	125	129	132	136	140	144	148	152	156
28	111	113	115	117	119	121	123	126	130	133	137	141	145	149	153	156
29	111	113	115	117	119	121	123	126	130	133	137	141	145	149	153	156
30	112	114	116	118	120	122	124	127	131	134	138	142	146	150	154	157
31	113	115	117	119	121	123	125	128	132	135	139	143	147	151	154	157
32	113	115	117	119	121	123	125	128	132	136	140	144	148	152	155	158
33	114	116	118	120	122	124	126	129	133	137	141	145	149	153	156	159
34	115	117	119	121	123	125	127	130	134	138	142	146	150	154	157	160
35	115	117	119	121	123	125	127	130	134	138	142	146	150	154	157	160
36	116	118	120	122	124	126	128	131	135	139	143	147	151	155	158	161
37	116	118	120	122	124	126	129	132	136	140	144	148	152	156	159	162
38	117	119	121	123	125	127	130	133	137	141	145	149	153	157	160	163
39	118	120	122	124	126	128	131	134	138	142	146	150	154	158	161	164
40	119	121	123	125	127	129	132	135	138	142	146	150	154	158	161	164
41	120	122	124	126	128	130	133	136	139	143	147	151	155	159	162	165
42	120	122	124	126	128	130	133	136	139	143	147	151	155	159	162	166
43	121	122	125	127	129	131	134	137	140	144	148	152	156	160	163	167
44	122	124	126	128	130	132	135	138	141	145	149	153	157	161	164	168
45	122	124	126	128	130	132	135	138	141	145	149	153	157	161	164	168
46	123	125	127	129	131	133	136	139	142	146	150	154	158	162	165	169
47	123	125	127	129	131	133	136	139	142	146	151	155	159	163	166	170
48	124	126	128	130	132	134	137	140	143	147	152	156	160	164	167	171
49	124	126	128	130	132	134	137	140	143	147	152	156	161	165	168	172
50	125	127	129	131	133	135	138	141	144	148	152	156	161	165	169	173
51	125	127	129	131	133	135	138	141	144	148	152	157	162	166	170	174
52	125	127	129	131	133	135	138	141	144	148	152	157	162	166	170	174
53	125	127	129	131	133	135	138	141	144	148	152	157	162	166	170	174
54	125	127	129	131	133	135	138	141	144	148	153	158	163	167	172	174
55	125	127	129	131	133	135	138	141	144	148	153	158	163	167	171	174

\* Allow 1½ inches for shoes and 6 pounds for clothes.

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## Chapter 63

### NORMAL BODY TEMPERATURE

CONSTANT body temperature is maintained in man, other mammals and birds, irrespective of changes in the environmental temperature. These are known as warm-blooded or homoiothermic animals. The body temperature of reptiles, amphibians and fishes is practically that of their environment. These are cold-blooded or poikilothermic animals.

The constant body temperature in homoiothermic animals is achieved by effecting a balance between heat production and heat dissipation. Heat production in the normal animal results chiefly from chemical reactions associated with the metabolism of food. Heat loss occurs through (1) radiation, convection and conduction; (2) evaporation of water from the lungs and skin; (3) raising the temperature of the expired air to that of the body; and (4) urine and feces. Radiation and convection account for about 70 per cent of the total loss of heat, and evaporation from the skin and lungs accounts for about 27 per cent.

In the normal adult the heat-regulating mechanism is extremely stable and efficient; however, whenever the heat production is not balanced by the heat lost to the environment, the body temperature rises or falls. Variations from the normal temperature occur in disease, muscular exertion, metabolism of food, mental excitement, prolonged exposure to markedly abnormal environmental changes and dehydration, and from the use of certain drugs.

The body temperature can be obtained by (1) *oral*, (2) *rectal* and (3) *axillary* temperature determinations.

Oral observations are generally used. If accurate results are to be achieved, a definite technic must be followed, to eliminate factors which might modify the oral temperature. A standardized clinical thermometer is placed in the mouth, under the tongue with the lips closed, and allowed to remain an absolute minimum of three minutes; better, five minutes. Shelly and Horvath<sup>8</sup> compared the temperature determinations when the thermometer was allowed to remain in position three and ten minutes. Their data indicate an infrequent and unimportant increase in the recorded temperature after the three-minute period, provided other factors are controlled.

An inaccurate oral temperature determination may result from a number of causes, including inadequate shaking down of the mercury, washing the thermometer in hot water before using it, breathing through the mouth or speaking while the thermometer is in place. Hot or cold foods or beverages should not be taken just before the temperature determinations.

Frequently disregarded sources of error in temperature determinations are abnormal mouth conditions. Extensive dental caries may raise the mouth temperature to give a reading of 37.8° C. (100° F.). An inflammation of the oral mucosa, such as dentoalveolar abscess, acute gingivostomatitis or a pericement-

titis, may cause an increase of mouth temperature to  $38.8^{\circ}$  to  $39.9^{\circ}$  C. ( $102^{\circ}$  to  $104.0^{\circ}$  F.).<sup>1</sup> Note should be taken of the presence of prosthetic appliances, bridges, crowns and the like, because they may occasion misleading records. Maxillary sinusitis may result in an elevation of the oral temperature in child.

Rectal temperature determinations as a rule are more accurate than oral determinations, since they are not so much affected by external and environmental factors. Rectal temperatures are used when it is desired to record slight rises in temperature and when temperatures of mouth breathers, infants and children and toxic patients must be taken. To secure accurate determinations, the mercury should be well shaken down and the thermometer allowed to remain in position an absolute minimum of three minutes.

Axillary temperature determinations are the most inaccurate method of evaluating body temperature. This procedure is used when it is impossible to take oral or rectal observations, as in a restless adult or uncooperative child.

The normal body temperature exhibits diurnal variations which depend on periods of rest and activity and the effect of differences in the day and night environmental temperatures. A diurnal temperature variation of 1 degree Centigrade (1.8 degree Fahrenheit) is not unusual. The minimum temperature occurs between four to six A. M., and may be as low as  $36.3^{\circ}$  C. ( $97.3^{\circ}$  F.); the maximum of  $37.3^{\circ}$  C. ( $99.1^{\circ}$  F.) occurs in the late afternoon. The oral temperature taken on awakening and before foods or liquids are placed in the mouth is often spoken of as the *basal temperature*.

In women ovarian activity modifies the basal temperature. It drops twenty-four to thirty-six hours before the onset of the menstrual period. It is elevated at the time of ovulation and during the first few months of pregnancy.<sup>2</sup>

The oral and rectal temperatures may be modified by climatic and environmental factors. Renbourn and Bonsall<sup>3</sup> found that the oral resting temperature in northern India during the summer months may be  $38.2^{\circ}$  C. ( $100.6^{\circ}$  F.) and furthermore, in hot climates the diurnal range is increased. Men working at temperatures of  $120^{\circ}$  F. and 36 per cent relative humidity had elevated oral and rectal temperatures.<sup>7</sup> The average oral temperature of these subjects was  $37.8^{\circ}$  C. ( $100.0^{\circ}$  F.), while their average oral temperature in a normal environment of  $75^{\circ}$  F., 50 per cent relative humidity, was  $36.8^{\circ}$  C. ( $98.0^{\circ}$  F.).

In temperate climates the average normal body temperature of a healthy adult (oral determination) is  $37.0^{\circ}$  C. ( $98.6^{\circ}$  F.), with a normal range of  $36.1^{\circ}$  to  $37.2^{\circ}$  C. ( $97.0^{\circ}$  to  $99.1^{\circ}$  F.). In some persons the extremes of normality may be even wider than this. Some individuals have habitually a body temperature of from 0.05 to 0.3 degrees Centigrade (0.1 to 0.5 degrees Fahrenheit) above or below the accepted normal. In children up to one year of age the normal temperature presents spontaneous variations of from 0.6 to 1.2 degrees Centigrade (1 to 2 degrees Fahrenheit). Unless otherwise specified, temperature recordings are assumed to be made by mouth.

Rectal temperature determinations average normally 1 degree Centigrade (1.8 degrees Fahrenheit) higher than the oral temperature, although according to Carmichael and Linder<sup>1</sup> the difference may range from 0.23 to 0.99 degree Centigrade (0.42 to 1.6 degree Fahrenheit). The oral temperature may ex-

rectal temperature in the absence of demonstrable local factors which may account for these findings. Rappaport<sup>1</sup> found that the oral temperature may be elevated to the abnormal range, without demonstrable organic disease. He believes that if the rectal temperature remains constantly normal, prolonged hospitalization and laboratory search for cryptogenic sepsis is unwarranted. Other instances of oral hyperthermia have been reported.

Under ordinary circumstances the measurements of axillary temperature may vary from 0.6 to 1.2 degrees Centigrade (1 to 2 degrees Fahrenheit) below that of the mouth.

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Section XVII  
ANATOMICAL NORMALS



# Chapter 64

## ANATOMICAL NORMALS

THIS CHAPTER contains tables of weights and measurements of various organs in the child and adult. Measurements for the embryo are given in Chapter 48. Measurements of certain organs, such as the genitalia, gastrointestinal tract and so forth, are included in their respective sections. Only values of everyday usefulness to the pathologist and clinician have been included. Those who desire further information concerning infrequently used values should consult the reference works noted in the bibliography.<sup>11, 12, 15, 16</sup> In addition, tables giving values of water, fat, nitrogen, chloride, common minerals, trace metals, sterol, and phospholipid concentrations of tissues have been added.

TABLE 323  
WEIGHT AND MEASUREMENTS OF VARIOUS ORGANS IN ADULTS

<i>Organ</i>	<i>Weight in Grams</i>	<i>Measurements in Centimeters</i>	
Brain:			
Male.....	1100-1700 (average 1400)	Sagittal diameter, 15-17	
Female.....	1050-1550 (average 1275)	Vertical diameter, 12.5	
Spinal cord.....	Average, 27	Length, 45	
		<i>Frontal</i>	<i>Sagittal</i>
Cervical.....		1.3-1.4	Average, 0.9
Thoracic.....		Average, 1	Average, 0.8
Lumbar.....		Average, 1.2	Average, 0.9
Pineal gland.....	Average, 0.2		
Heart and Vessels: <sup>19</sup>			
Male.....	270-360 (average 300)		
Female.....	200-280 (average 250)		
		<i>Range</i>	<i>Average</i>
Left ventricle muscle....			1.5
Right ventricle muscle....			0.5
Auricular muscle.....			0.2
Mitral valve.....		8-10.5	10.0
Aortic valve.....		6-7.5	7.5
Pulmonary valve.....		7-9	8.5
Tricuspid valve.....		10-12.5	12.0
Pulmonary artery.....			8.0
Aorta:			
Ascending.....			7.4
Thoracic.....			5.0
Abdominal.....			4.0
Lungs:			
Right.....	360-570 (average 450)		
Left.....	325-480 (average 375)		
Liver.....	1500-1800 (average 1650)	25-30 by 19-21 by 6-9	
Spleen: <sup>9</sup>		12-14 by 8-9 by 3-4	
16-20 years.....	150-200 (average 170)		
20-65 years.....	Average, 155		
80 years and over.....	Average, 100		
Pancreas.....	60-135 (average 110)	23 by 4.5 by 3.8	
Kidneys:*		11-12 by 5-6 by 3-4	
Male.....	230-440 (average 313)		
Female.....	240-350 (average 288)		

\*More extensive weights and measurements of the kidneys are given in Tables 186 and 187, p. 327.

TABLE 323—*Continued*

<i>Organ</i>	<i>Weight in Grams</i>	<i>Measurements in Centimeters</i>
Prostate:		3.6 by 2.8 by 1.9
20-30 years	Average, 15	
51-60 years	Average, 20	
71-80 years	Average, 40	
Seminal vesicles		4.1-4.5 by 1.6-1.8 by 0.9
Uterus:		
Virgin	33-41 (average 35)	7.8-8.1 by 3.4-4.5 by 1.8-2.7
After pregnancy	102-117 (average 110)	8.7-9.4 by 5.4-6.1 by 3.2-3.6
Cervix (virgin)		2.9-3.4 by 2.5 by 1.6-2
Endocrines:		
Pituitary:		2.1 by 1.4 by 0.5
10-20 years	Average, 0.56	
20-70 years	Average, 0.61	
Pregnancy	0.84-1.06 (average 0.95)	
Thyroid	30-70 (average 40)	5-7 by 3-4 by 1.5-2.5
Testis:		
Newborn		1 by 0.5 by 0.4
Puberty		3 by 2 by 1.6
Adult	20-27 (average 25)	4-5 by 2.5-3.5 by 2-2.7
Ovary:		
Virgin		4.1-5.2 by 2-2.7 by 1-1.1
After pregnancy	Average, 7	2.7-4.1 by 1.5 by 0.8
Adrenal	Average, 6	4.5 by 2.5-3.5 by 0.5
Parathyroids	0.12-0.18	0.3-0.6 by 0.2-0.4 by 0.05-0.2 (ea
Thymus:		
Newborn	6.05-25.88 (average 13.98)	
1-9 months	6.74-34.10 (average 20.14)	
9-24 months	19.97-37.72 (average 26.60)	
6-25 years	Average, 25	
26-35 years	Average, 20	
36-65 years	Average, 16	
65 years and over	Average, 6	
Gastrointestinal tract:		
Esophagus		25
Duodenum		30
Small intestine		550-650
Colon		150-170

TABLE 324  
ORGAN WEIGHTS IN CHILDREN\*  
(Coppoletta and Wolbach, 1933)<sup>4</sup>

Age	Body Length	Heart	Lungs		Spleen	Liver	Kidneys		Brain
			Right	Left			Right	Left	
	Cm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.	Gm.
Birth-3 days.....	49	17	21	18	8	78	13	14	335
3-7 days.....	49	18	24	22	9	96	14	14	358
1-3 weeks.....	52	19	29	26	10	123	15	15	382
3-5 weeks.....	52	20	31	27	12	127	16	16	413
5-7 weeks.....	53	21	32	28	13	133	19	18	422
7-9 weeks.....	55	23	32	29	13	136	19	18	489
3 months.....	56	23	35	30	14	140	20	19	516
4 months.....	59	27	37	33	16	160	22	21	540
5 months.....	61	29	38	35	16	188	25	25	644
6 months.....	62	31	42	39	17	200	26	25	660
7 months.....	65	34	49	41	19	227	30	30	691
8 months.....	65	37	52	45	20	254	31	30	714
9 months.....	67	37	53	47	20	260	31	30	750
10 months.....	69	39	54	51	22	274	32	31	809
11 months.....	70	40	59	53	25	277	34	33	852
12 months.....	73	44	64	57	26	288	36	35	925
14 months.....	74	45	66	60	26	304	36	35	944
16 months.....	77	48	72	64	28	331	39	39	1010
18 months.....	78	52	72	65	30	345	40	43	1042
20 months.....	79	56	83	74	30	370	43	44	1050
22 months.....	82	56	80	75	33	380	44	44	1059
24 months.....	84	56	88	76	33	394	47	46	1064
3 years.....	88	59	89	77	37	418	48	49	1141
4 years.....	99	73	90	85	39	516	58	56	1191
5 years.....	106	85	107	104	47	596	65	64	1237
6 years.....	109	94	121	122	58	642	68	67	1243
7 years.....	113	100	130	123	66	680	69	70	1263
8 years.....	119	110	150	140	69	736	74	75	1273
9 years.....	125	115	174	152	73	756	82	83	1275
10 years.....	130	116	177	166	85	852	92	95	1290
11 years.....	135	122	201	190	87	909	94	95	1320
12 years.....	139	124	...	...	93	936	95	96	1351

\* The weights and body lengths represent averages. Considerable variation is to be expected. When a child is large or small for its age, it is often better to use as normals the weights which correspond to the body length.

TABLE 325  
BRAIN WEIGHT IN GRAMS AT VARIOUS AGES  
(Bischoff, 1880)<sup>2</sup>

<i>Age in Years</i>	<i>Males</i>			<i>Females</i>		
	Number	Weight	Range	Number	Weight	Range
17-19 . . . . .	16	1340	1170-1527	19	1242	1120-1423
20-29 . . . . .	86	1396	1158-1620	93	1234	1057-1566
30-39 . . . . .	182	1365	1075-1685	96	1233	1038-1444
40-49 . . . . .	96	1366	1069-1605	44	1240	995-1541
50-59 . . . . .	96	1375	1113-1665	39	1200	820-1441
60-69 . . . . .	45	1323	1018-1610	32	1178	920-1373
70-85 . . . . .	24	1279	1039-1485	18	1121	832-1370

TABLE 326  
NORMAL WEIGHT OF THE HEART  
(Bean and Baker, 1919)<sup>1</sup>

<i>Group</i>	<i>Number of Subjects</i>	<i>Weight (Gm.)</i>	<i>Range</i>
White males . . . . .	35	317.6	200-530
Negro males . . . . .	42	342.9	250-470
White females . . . . .	18	260.0	180-310
Negro females . . . . .	3	216.0	198-250

TABLE 327  
NORMAL WEIGHT OF THE LIVER  
(Bean and Baker, 1919)<sup>1</sup>

<i>Group</i>	<i>Number of Subjects</i>	<i>Weight (Gm.)</i>	<i>Range</i>
White males . . . . .	41	1664	1100-2600
Negro males . . . . .	46	1443	980-2270
White females . . . . .	12	1407	1100-2030
Negro females . . . . .	4	1201	850-1560

TABLE 328  
ADRENAL AND TESTIS WEIGHTS AT VARIOUS BODY LENGTHS  
(Leupold, 1920)<sup>9</sup>

Body Length (Cm.)	Number of Subjects	Adrenal		Testis	
		Weight (Gm.)	Range	Weight (Gm.)	Range
58-162.....	14	10.0	7.0-13.2	24.2	16.6-38.4
70.....	16	11.1	7.7-18.6	24.2	15.7-36.3
74-176.....	12	11.5	8.2-18.2	28.8	15.8-35.0
78-182.....	9	14.8	9.6-20.3	30.3	13.8-49.4

TABLE 329  
DEVELOPMENT OF THE SEX ORGANS  
(Weissenberg, 1911)<sup>18</sup>

Age in Years	Penis Length (Mm.)	Prostate (Gm.)	Testes (Gm.)		Seminal Vesicle (Gm.)	Uterus (Gm.)	Ovary (Gm.)	
			Right	Left			Right (Gm.)	Left (Gm.)
Birth.....	28	0.9	0.2	0.2	0.05	4.6	0.2	0.2
1.....	32	1.2	0.7	0.7	0.08	2.3	0.5	0.5
2.....	35	...	0.9	0.9	0.09	1.9	0.5	0.4
3.....	35	1.1	0.9	0.9	0.09	2.5	0.7	0.7
4.....	35	...	0.9	0.9	0.09	...	0.7	0.7
5.....	35	1.2	0.9	0.9	0.09	2.9	1.1	1.0
6.....	40	...	...	...	....	2.9	1.1	1.1
7.....	40	...	...	...	....	2.6		
8.....	40	1.3	0.8	0.8	0.1	2.6	1.6	1.5
9.....	40	...	0.8	0.8	0.1	3.4	1.6	1.5
10.....	40	1.4	0.8	0.8	0.1	3.4	1.6	1.5
11.....	40	2.3	1.2	1.3	....	5.3	2.2	2.1
12.....	40	2.8	1.5	1.5	0.12	5.3	2.2	2.1
13.....	40	3.7	...	...	....	15.9		
14.....	75	3.5	1.5	1.5	0.15			
15.....	75	5.1	6.8	6.8	1.5			
16.....	90	6.1	...	...	....	43.0	2.0	2.0
17.....	....	11.4						
21-25.....	....	17.9	...	...	....	48.0		

TABLE 330  
DETERMINATION OF THE AGE OF THE HUMAN AFTER BIRTH  
(Friedenthal)<sup>6</sup>

<i>Age</i>	<i>Skin</i>	<i>Tooth System</i>	<i>Bones</i> (Centers of Ossification)
1-3 months . . . . .	Navel dries 3rd day, falls off in 4-5 days, heals in 7 days	Tooth cone for upper first molar	Cuneiform 3
4-8 months . . . . .	.....	Incisor teeth: 1st: 7-9 months 2d: 8-10 months	Upper epiphysis of humerus, capitate: male, 10 months, female, 6 months; hamate male, 5-10 months, female, 6-12 months
9-12 months . . . . .	.....	.....	Distal epiphysis of tibia
12-15 months . . . . .	.....	1st milk molars	
16-20 months . . . . .	.....	Milk canines	
2 years . . . . .	.....	2d milk molars	Distal epiphysis of fibula, coracoid, acromioclavicular joint
3 years . . . . .	.....	Tooth cone for 2d upper molar	Head of 3rd metacarpal, blade of 3rd phalanx, hamate, capitate, distal epiphysis of ulna, head of humerus
4 years . . . . .	.....	.....	Cuneiform 1, upper epiphysis of fibula, base of 1st metacarpal, epiphysis of toe phalanges, 2d row
5 years . . . . .	.....	.....	Femur-great trochanter, patella, fibula, lunate, navicular
6 years . . . . .	.....	.....	Head of radius, greater and lesser multangular bones
7 years . . . . .	.....	.....	Navicular (foot), femur greater trochanter, epiphysis of ischium, process of sternum
8 years . . . . .	.....	1st molar 1st permanent incisor	Medial epicondyle of humerus, carpal epiphysis of ulna
9 years . . . . .	.....	2d incisor	Calcaneus-epiphysis of the tuberosity

TABLE 330—*Continued*

<i>Age</i>	<i>Skin</i>	<i>Tooth System</i>	<i>Bones</i> ( <i>Centers of Ossification</i> )
0 years.....	.....	.....	Pisiform, proximal epiphysis of ulna
1-12 years.....	Beginning of pubic hair in female	1st premolar 2d premolar Canine	Olecranon—2 centers, acetabulum
14 years.....	Beginning of pubic hair in male	2d molars	Distal epiphysis of humerus—3 centers, femur—small trochanter, sesamoid of great toe
16 years.....	Beginning of beard growth in males		Coracoid, sesamoid of hand, epiphysis of angle of scapula
17-18 years.....	.....	.....	Acetabulum completely ossified, epiphysis of finger, olecranon fusion, epiphysis of head of radius
19-20 years.....	.....	3rd molars (18-25 years)	Inferior angle of scapula, 2d epiphysis of the coracoid process, fusion of the proximal epiphysis of humerus, sternal epiphysis of clavicle
21-25 years.....	Chest and axillary hair	.....	Closure of spheno-basilar suture, fusion of crest of ilium
25-30 years.....	Beginning of hair falling	.....	Fusion of ensiform process of sternum
30-35 years.....	Baldness begins		
40-45 years.....	.....	.....	First cranial suture ossification
45-50 years.....	.....	Loss of several teeth	
51-60 years.....	Greying of hair and beard		
60-80 years.....	Whitening of head and body hair		
80-100 years....	Loss of lanugo hair of body	Loss of all teeth	Calcium depletion of skeleton

## CHLORIDE IN TISSUES

Chloride is distributed throughout the body and may vary from 1 to 75 per cent of the total anions present in different tissues and intercellular fluids. However, its percentage in any given structure under normal conditions appears to be relatively constant. The intercellular structures, in contrast to the cells, are especially rich in this anion. Most of the chloride in the body is in inorganic combination, but there is evidence to suggest that a part of it may be present as organic chloride. Values for chloride in tissues are given in Tables 330a, 331, 332 and 333.

TABLE 330a

## CHLORIDE IN TISSUES

(Sunderman, 1932)<sup>14</sup>

<i>Material</i>	<i>Chloride as NaCl (Mg. Per Cent of Wet Tissue)</i>
Serum (human).....	576-611
Corpuscles (human).....	307
Whole blood (human).....	451-529
Muscle (human).....	100, 103, 115
(Beef).....	85
Lung (human).....	379, 402
Intestines (human).....	100
Liver (human).....	158, 218, 172-341
(Beef).....	187
Testicle (human).....	372
Ovary (human).....	395
Brain (gray matter).....	186
(White matter).....	249
Spinal cord (human).....	250
Skin (dog).....	619
Heart (beef).....	161
Kidney (dog).....	348-504
(Beef).....	321
Entire body (human).....	203
(Mouse).....	234

TABLE 331

MINERAL CONTENT PER KILOGRAM OF THE WHOLE BODY AT DIFFERENT AGES, AND OF ADULT ORGANS, ON A FAT-FREE BASIS  
(Shohl, 1939)<sup>13</sup>

Whole Body	Fat (Per Cent)	Water (Per Cent)	Na (Gm.)	Na (mEq.)	K (Gm.)	K (mEq.)	Ca (Gm.)	Ca (mEq.)	Mg (Gm.)	Mg (mEq.)	Cl (Gm.)	Cl (mEq.)	P (Gm.)	P (mM.)	S (Gm.)	S (mEq.)
Fetus, 3-4 mo.....	0.5	93														
5 mo.	1.2	91	2.58	112	2.00	51	3.4	170	0.18	15	2.7	76	2.14	69		
6 mo.	2.5	87	2.16	94	1.62	41	5.9	295	0.21	17	2.5	70	3.58	115	1.48	92
7 mo.	2.5	86	2.14	93	1.88	48	6.2	310	0.21	17	2.5	70	3.82	123	1.80	113
Premature, 7 mo.	3.0	85	2.42	105	1.71	44	7.5	310	0.22	18	2.6	73	3.82	123	1.53	96
Newborn	12.0	80	1.78	78	1.90	49	9.2	460	0.22	18	2.7	75	3.82	123		
Adult	18.0	72	1.09	48	2.65	68	20.1	1000	0.27	23	2.0	56	5.40	174	2.46	154
									0.36	30	1.56	42	11.6	374	1.96	123
Adult Organs																
Muscles	7.5	79	0.72	31	3.60	93	0.07	4	0.23	19	0.66	18	2.20	71	2.5	
Skeleton	10.0	44	1.8	79	0.61	16	110	5250	1.05	88	1.9	54	50.5	1630		
Blood serum	0.6	92	3.35	145	0.20	5	0.11	5	0.03	3	3.70	104	0.15	5	0.001	
Blood cells	0.6	65	?	?	4.20	108			0.06	5	1.93	54	1.00	32	0.001	
Skin.....	15.0	73	1.6	70	1.07	27	0.20	10	0.14	11	3.0	85	0.65	21		
Brain.....	12.6	90	1.7	75	3.3	85	0.12	6	0.16	13	0.15	42	3.8	122	1.3	
Liver.....	21.3	79	1.9	82	2.15	55	0.12	6	0.22	18	1.6	45	2.1	69	1.9	
Intestine.....	6.5	85			2.9	70	0.14	7	0.08	6	0.65	18	1.00	32	1.20	
Lungs.....	1.7	78	2.5	109	1.5	39	0.17	8	0.07	6	2.6	73	1.2	39	1.27	
Kidney.....	5.2	80	1.75	72	1.75	45	0.20	10	0.21	17	2.2	62	1.4	45		
Heart.....	8.3	77	1.85	80	2.50	64	0.10	5	0.17	14	1.35	38	2.70	87		
Spleen.....	3.0	77					0.10	5	0.15	12	1.6	45	3.8	122	1.70	
Pancreas.....	10.5	80	0.87	38	2.26	58	0.17	8	0.19	16	1.8	51	3.4	110		
Thyroid.....	4.4								0.10	8	1.8	51	3.4	110		
Testicle.....	4.5						0.09	4	0.10	8	2.4	67		18		
Uterus.....			1.45	63	1.45	37	0.22	11	0.16	13	2.6	74	0.57			
Adrenal.....					1.03	26	0.16	8	0.10	8	2.4	67				

TABLE 332  
MINERAL CONTENT OF THE WHOLE BODY AT DIFFERENT AGES  
(Shohl, 1939)<sup>13</sup>

	Total Weight (Gm.)	Fat (Gm.)	Water (Gm.)	Dry Weight (Gm.)	Ash (Gm.)	N (Gm.)	Na (Gm.)	K (Gm.)	Ca (Gm.)	Mg (Gm.)	Cl (Gm.)	P (Gm.)	S (Gm.)
Fetus, 3-4 mo.....	126	0.6	116	10	1.5	1.0	1.29	1.0	0.42	0.022	0.34	0.27	
5 mo.....	500	5	455	45	8.5	6.0	1.85	1.4	2.9	0.10	1.25	1.8	0.74
6 mo.....	880	19	755	125	19.0	12	2.4	2.1	5.3	0.17	1.60	3.25	1.55
7 mo.....	1155	32	975	180	30	20	2.8	2.1	6.9	0.23	2.95	4.3	1.7
Premature, 7 mo.....	1190	36	970	220	32	20			8.6	0.25	3.05	4.4	
	(Kg.)	(Kg.)	(Kg.)	(Kg.)	(Kg.)								
Newborn.....	2.9	0.35	2.08	0.8	0.1	55	4.7	5.1	23.6	0.7	5.0	13.8	6.3
Adult.....	70.0	12.6	41.4	29.0	3.0	2100	63.0	150.0	1160.0	21.0	85.0	670.0	112.0

TABLE 333

WEIGHTS OF THE ORGANS OF THE NEWBORN AND ADULTS, AND MINERAL CONTENT OF ADULT ORGANS  
(Shohl, 1939)<sup>13</sup>

Organ	Newborn			Adults									
	Weight		Weight (Kg)	Fat (Kg)	H <sub>2</sub> O (Kg)	Na (Gm.)	K (Gm.)	Ca (Gm.)	Mg (Gm.)	Cl (Gm.)	P (Gm.)	S (Gm.)	
	(Kg)	(Per Cent)											
Whole body	3.1	25.1	66.2	2.1	21.0	19.1	109.0	1.85	6.10	13.5	58.5	60	
Muscles	0.78	13.7	28.7	1.1	5.1	18.7	6.4	1150.00	11.0	20.	530	16	
Skeleton	0.43		11.6		2.5	9.1	0.5	0.27	0.09	10.	0.4		
Blood serum	0.13	6.5	2.7	0.03	1.2	?	7.6	?	0.11	5.2	1.8		
Blood cells	0.06		1.8						0.5	12.2	2.4	18	
Skin	0.61	19.7	4.8	0.7	3.1	6.5	4.4	0.8	0.5	16			
Subcutaneous tissue.			12.6	8.2	4.2								
Brain	0.38	12.3	1.4	0.17	1.1	2.1	4.1	0.15	0.2	1.8	4.6	2.9	
Liver	0.14	4.6	1.8	0.38	1.1	2.7	3.1	0.17	0.31	2.3	3.2	0.5	
Intestines	0.07	2.1	1.4	0.13	1.1	3.0	4.5	0.21	0.12	1.0	1.5		
Lungs	0.05	1.8	1.0	0.02	0.8	2.4	1.5	0.17	0.07	2.6	1.2		
Kidney	0.02	0.8	0.3	0.015	0.2	0.5	0.5	0.07	0.07	0.7	0.4		
Heart	0.02	0.8	0.3	0.025	0.2	0.4	0.3	0.03	0.05	0.4	0.6		
Spleen	0.01	0.3	0.16	0.005	0.1			0.02	0.02	0.3	0.3		
Pancreas	0.004	0.1	0.1	0.010	0.1	0.8	0.2	0.02	0.02	0.2	0.3		

ANATOMICAL NORMALS

TABLE 334  
APPROXIMATE PHOSPHOLIPID CONTENT OF TISSUES (AS LECITHIN)  
(Everett, 1942)<sup>5</sup>

	<i>Per Cent</i>
Brain:	
White.....	9.0
Gray.....	4.0
Spinal cord.....	9.0
Bone marrow.....	2.8*
Kidney, liver.....	2.5
Adrenal, pancreas, testes.....	2.0
Heart, lung.....	1.5
Intestine, muscle, spleen, stomach.....	1.0
Blood, bones, skin.....	0.3
Lymph.....	0.2
Milk.....	0.02

\* Higher values in the infant.

TABLE 335  
APPROXIMATE TOTAL STEROL CONTENT OF TISSUES  
(Everett, 1942)<sup>5</sup>

	<i>Mg. per Cent</i>
Adipose tissue.....	170
Adrenal.....	5000
Bile, hepatic.....	100
Blood.....	210
Brain:	
White.....	4000
Gray.....	1000
Kidney.....	430
Liver.....	350
Lung.....	375
Milk.....	12
Muscle:	
Smooth.....	150
Striated.....	60
Pancreas.....	310
Skin.....	1400
Spleen.....	250

TABLE 336  
DISTRIBUTION OF LEAD IN HUMAN TISSUE  
(After Badham and Taylor)<sup>3</sup>

	<i>Normal</i> <i>(Mg. per Cent)</i>	<i>Painter</i> <i>(Mg. per Cent)</i>	<i>Lacquering</i> <i>(Mg. per Cent)</i>
Long bones.....		0.72	
Sternum.....	0.04	1.48	0.08
Brain.....	0.00	0.27	0.10
Kidneys.....	0.09	0.08	0.11
Lungs.....	0.00	0.05	0.06
Liver.....	0.07	0.34	0.26
Heart.....			0.13
Muscle.....		0.05	

TABLE 336a

THE CONCENTRATION LEVELS OF TRACE METALS IN NORMAL HUMAN TISSUES (AMERICANS)  
(ARITHMETICAL MEAN VALUES)  
(Kehoe, Cholak and Story, 1940)<sup>7</sup>

Tissue	Milligrams of Metal Per 100 Gm. of Wet Tissue					
	Mn	Pb	Sn	Al	Cu	Ag
kidney.....	0.060	0.027	0.020	0.042	0.166	0.00
heart.....	0.032	0.038	0.022	0.056	0.190	0.00
rain.....	0.030	0.013	0.00	0.004	0.400	0.003
iver.....	0.205	0.130	0.060	0.160	0.710	0.005
pleen.....	0.022	0.030	0.022	0.130	0.085	0.00
ung.....	0.022	0.028	0.045	5.94	0.110	0.004
muscle.....	0.050	0.010	0.011	0.015	0.125	0.00
ong bone.....	0.300	1.88	0.080	0.500	1.190	0.00
ib bone.....	0.170	0.470	0.050	0.240	0.410	0.01
tomach.....	0.030	0.022	0.050	0.073	0.107	0.00
ntestines.....	0.035	0.023	0.016	0.087	0.110	0.002

RADIUM: The average content of radium in the whole body is approximately  $1 \times 10^{-10}$  grams (see table 402, p. 798).

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Section XVIII

TEETH AND SALIVA

(Normal Values in Dentistry)



## Chapter 65

### FORMATION AND ERUPTION OF TEETH

TABLE 337 GIVES the ages at which the deciduous and permanent teeth begin to calcify and are completed. Table 338 gives the ages at which the individual teeth erupt in human beings.

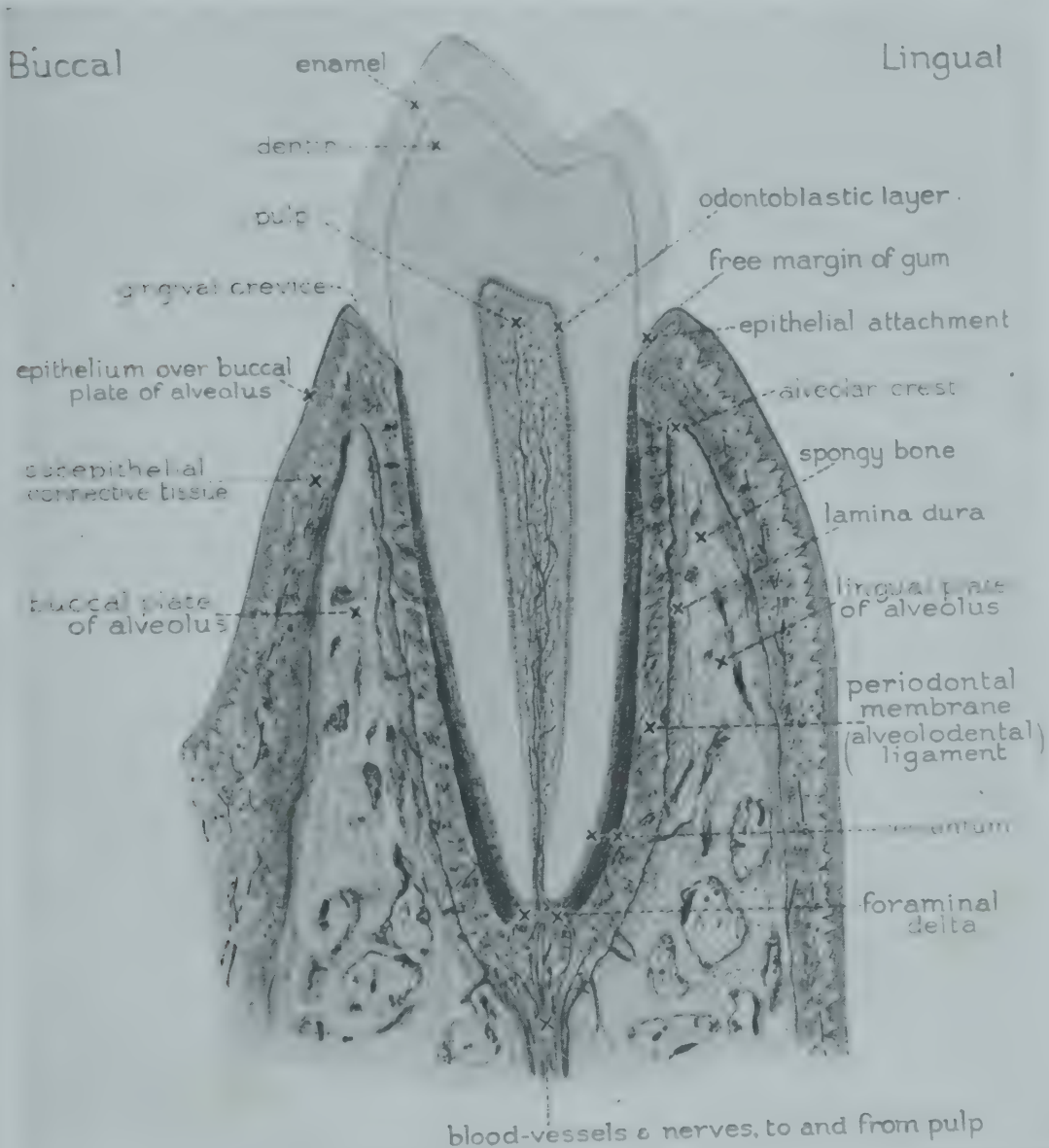


Fig. 213. Diagram of a longitudinal section of a tooth in buccolingual direction in situ. (Pucci, El Paradencio, Casa A. Barreiro y Ramos.)

The tooth with the greatest variation of eruption time is the second molar. It may erupt in one child at the age of eighteen months, but in another child not until the age of three years or later.

Robinow and his co-workers<sup>15</sup> state that the laterals show the greatest variability.

Boys were slightly more advanced than girls in the eruption of all deciduous teeth except first molars. The eruption of all teeth was more variable

TABLE 337  
CHRONOLOGY OF HUMAN DENTITION  
(Logan and Kronfeld, 1938)<sup>10</sup>  
Deciduous Dentition—Upper and Lower

Teeth	First Evidence of Calcification (In Utero)	Crown Completed (After Birth)	Root Completed (After Birth)
Central incisors . . . . .	5 months	4 months	1½–2 years
Lateral incisors . . . . .	5 months	5 months	1½–2 years
Canines . . . . .	6 months	9 months	2½–3 years
First molars . . . . .	5 months	6 months	2–2½ years
Second molars . . . . .	6 months	10–12 months	3 years

Permanent Dentition—Upper

Teeth	First Evidence of Calcification (After Birth)	Crown Completed (After Birth)	Root Completed (After Birth)
Central incisors . . . . .	3–4 months	4–5 years	10 years
Lateral incisors . . . . .	1 year	4–5 years	11 years
Canines . . . . .	4–5 months	6–7 years	13–15 years
First premolars . . . . .	1½–1¾ years	5–6 years	12–13 years
Second premolars . . . . .	2–2¼ years	6–7 years	12–14 years
First molars . . . . .	At birth	2½–3 years	9–10 years
Second molars . . . . .	2½–3 years	7–8 years	14–16 years
Third molars . . . . .	7–9 years	12–16 years	18–25 years

Permanent Dentition—Lower

Central incisors . . . . .	3–4 months	4–5 years	9 years
Lateral incisors . . . . .	3–4 months	4–5 years	10 years
Canines . . . . .	4–5 months	6–7 years	12–14 years
First premolars . . . . .	1¾–2 years	5–6 years	12–13 years
Second premolars . . . . .	2¼–2½ years	6–7 years	13–14 years
First molars . . . . .	At birth	2½–3 years	9–10 years
Second molars . . . . .	2½–3 years	7–8 years	14–15 years
Third molars . . . . .	8–10 years	12–16 years	18–25 years

girls than in boys. The lateral incisors were most variable in their eruption in both sexes.<sup>15</sup>

Data were collected from examination of 1962 white children of fairly low economic status who were under regular nutritional and medical supervision.

TABLE 338  
ERUPTION OF TEETH ACCORDING TO AGE  
(Logan and Kronfeld, 1941)<sup>11</sup>

Tooth	Deciduous Eruption (Age in Months)	Permanent Eruption (Age in Years)	
		Upper Teeth	Lower Teeth
Central incisor.....	6-7½	7-8	6-7
Lateral incisor.....	7-9	8-9	7-8
Cuspid.....	16-18	11-12	9-10
First bicuspid.....	.....	10-11	10-12
Second bicuspid.....	.....	10-12	11-12
First molar.....	12-14	6-7	6-7
Second molar.....	20-24	12-13	11-13
Third molar.....	.....	17-21	17-21

TABLE 339  
ERUPTION OF DECIDUOUS TEETH\*  
(Doering and Allen, 1942)<sup>6</sup>

Teeth	Age Range in Months	Percentage of Children
Upper centrals.....	6-12	88
Lower centrals.....	6-12	80
Upper laterals.....	6-12	66
Lower laterals.....	12-18	61
First molars.....	12-18	81
Canines.....	18-24	58
Second molars.....	24-30	54

\* The sample was considered representative of a middle class population, around Boston. The families for the most part were of northern European stock.

TABLE 340  
AGE IN MONTHS WHEN INDIVIDUAL DECIDUOUS TEETH ERUPT\*  
(Robinow et al., 1942)<sup>15</sup>

Tooth	Boys				Girls			
	Upper		Lower		Upper		Lower	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Central incisor.....	9.1	1.5	7.3	1.6	9.6	2.0	7.8	2.1
Lateral incisor.....	10.4	2.4	13.0	2.8	11.9	2.7	13.8	3.6
Canine.....	18.9	2.7	19.3	2.9	20.1	3.2	20.2	3.4
First molar.....	16.0	2.3	16.2	1.9	15.7	2.3	15.6	2.2
Second molar.....	27.6	4.4	25.9	3.8	28.4	4.3	27.1	4.2

\* Sixty-four presumably normal, healthy white children in Ohio.

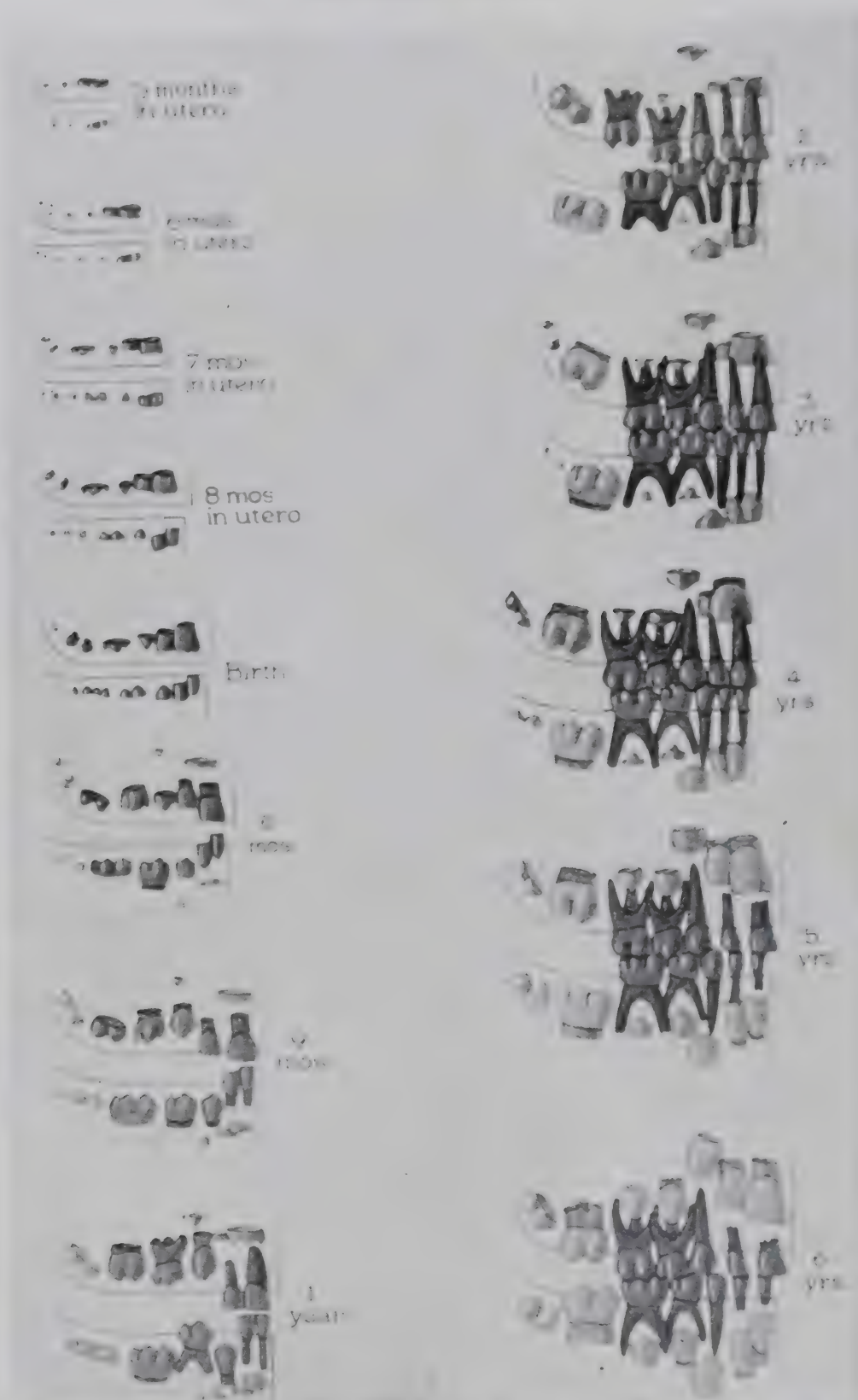


Fig. 214. Development of the human dentition. (Schour, I., and Massler, M.; distributed the Bureau of Public Relations, American Dental Association.)

a well-baby clinic (New York City) during the fall and winter of 1941-42. The seemed to be no characteristic differences between boys and girls as to the age at which specific teeth erupt, nor in respect to the number of teeth to be expected

any age. No deciduous tooth erupted in children under four months of age. deciduous teeth had erupted in all children over thirty-four months of age.

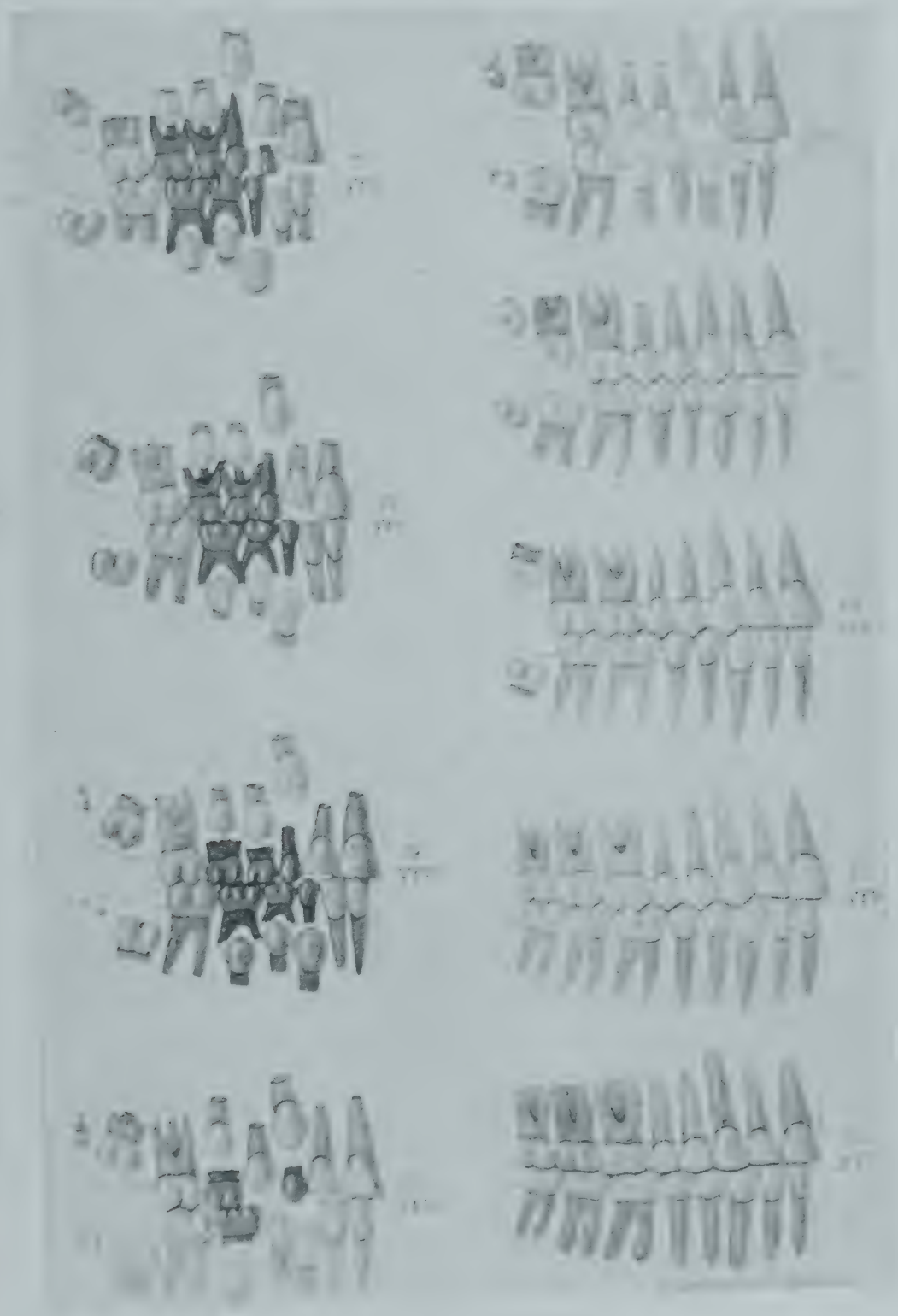


Fig. 214—Continued.

Meredith<sup>12</sup> has made the following generalizations on the eruption of the deciduous teeth in North American children:

1. Infants rarely erupt teeth before the end of their fourth postnatal month.

2. The mean age for eruption of the first tooth is 7.5 months. The most diverse averages reported for eruption of the first tooth are 5.6 months and 10.5 months.

3. A few infants do not begin to erupt teeth until early in the second postnatal year. Approximately 1 per cent of white infants erupt their first tooth after one year of age.

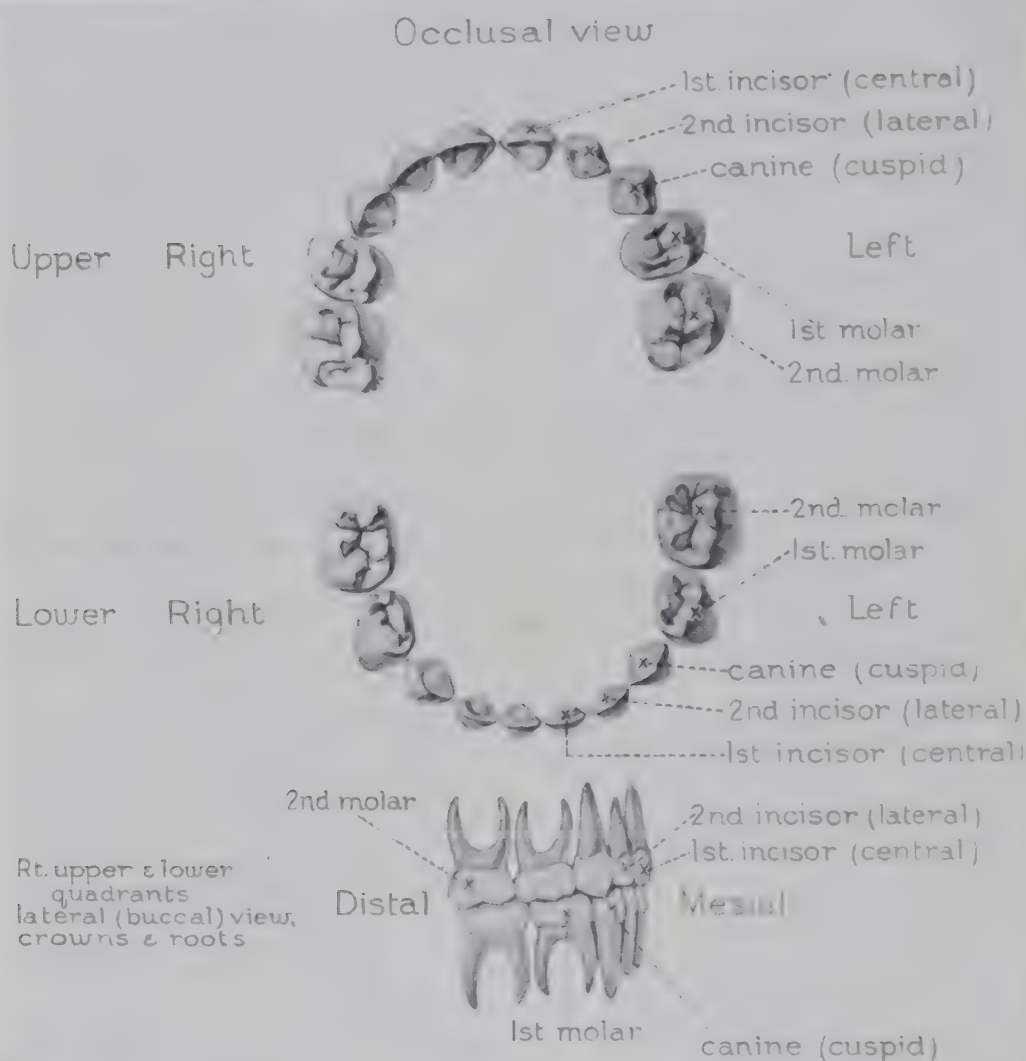


Fig. 215. Normal complement of the deciduous dentition. (Massler, M., and Schour, I.: *Anatomy of the Mouth*, American Dental Association.)

4. At six months of age approximately one infant in three has one or more erupted teeth.

5. At the age of nine months the average infant has three erupted teeth. The usual range of individual variation is from none to eight teeth. About 10 per cent of white infants have no teeth, 80 per cent have between one and six teeth and 10 per cent more than six teeth. For each sex separately, the means are 3.1 erupted teeth in 350 males and 2.7 in 320 females. Among those infants erupting

At six months by nine months, there are roughly three times as many males as females.

6. In infants one year of age the number of erupted teeth is rarely less than two or more than ten. A few infants have no teeth and a few have twelve or more. Fifty per cent of one-year old infants have between four and eight teeth.

7. The typical, or median, number of erupted teeth is twelve in children fifteen months of age and sixteen in children two years of age. For white

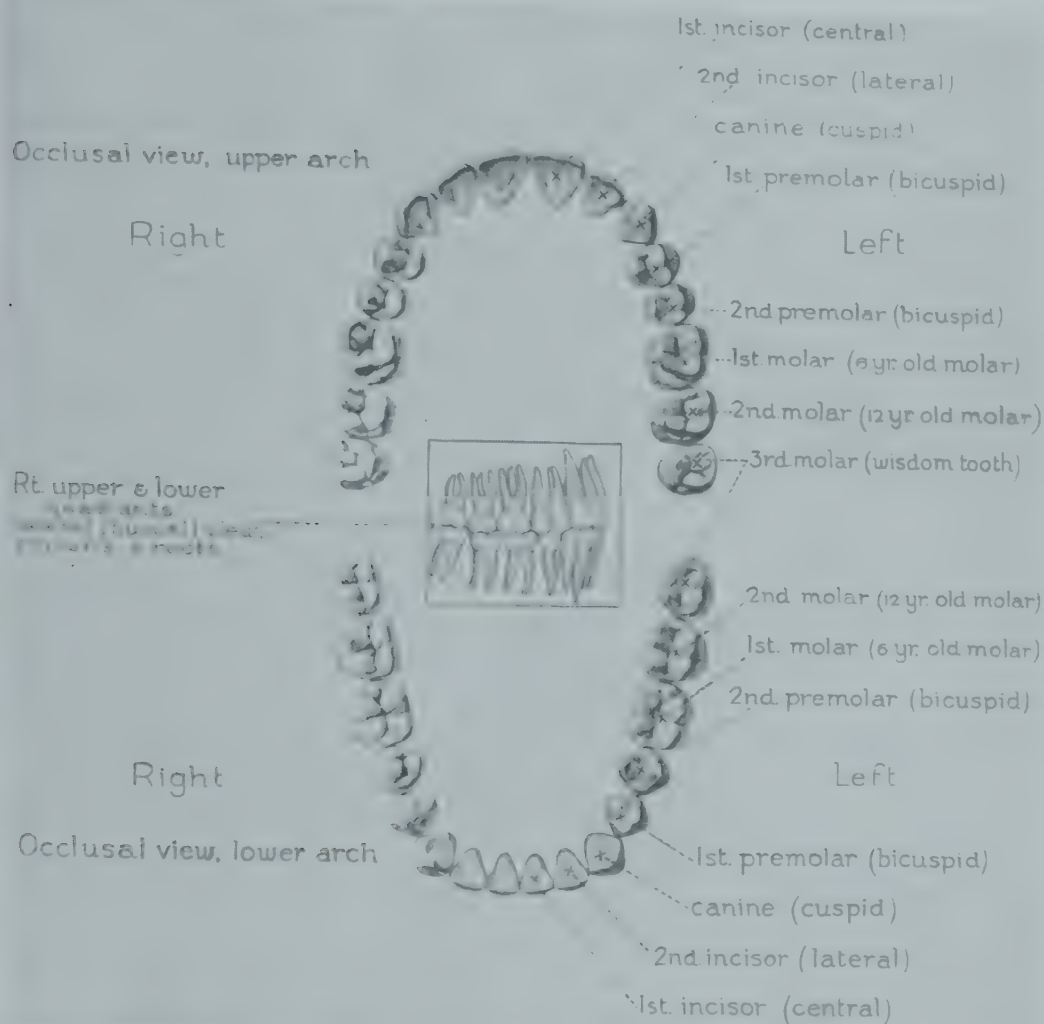


Fig. 216. Normal complement of the permanent dentition. (Massler, M., and Schour, I.: Atlas of the Mouth, American Dental Association.)

Infants aged eighteen months, about 10 per cent have four to eight teeth, 85 per cent nine to sixteen teeth, and 5 per cent seventeen to twenty teeth. Composite mean values at this age are 12.7 for 245 males and 12.5 for 255 females. White infants aged two years vary, with roughly 15 per cent having eight to fourteen teeth, 60 per cent fifteen to eighteen teeth, and 25 per cent nineteen to twenty teeth. Composite means at two years are 16.9 for 260 males and 16.5 for 250 females.

8. At two and one-half years of age 30 per cent of white children have

twelve to nineteen erupted teeth and 70 per cent the full deciduous complement. The mean number of teeth at this age is 19.2 for males and 19.0 for females. The typical (median) child has twenty teeth. Data for exact age at eruption of the last deciduous tooth give means of 28.2 months on 128 white males and 28.3 months on ninety-seven Negro males. Roughly, 90 per cent of children have complete eruption of the deciduous teeth between two and three years of age. Individuals still lacking eruption of the full deciduous complement have been observed at thirty-seven months.

9. There are wide individual differences in the timing of eruption of deciduous teeth: Some children erupt a given tooth early, others late; some erupt the full deciduous complement in a short period, others spread their twenty eruptions over an extended time interval. From the standpoint of the number of teeth present in the mouth at different ages, variation is greatest during the first half of the second year. Records manifesting the maximum scatter attainable (i. e., no erupted teeth in one child and a full complement in another) have been obtained on Negro subjects aged twelve months and on white subjects aged thirteen months. The standard deviation is largest around eighteen months. Minimum and maximum records for the number of erupted teeth at this age are four and twenty.

Turning to the consideration of the age span during which given numbers of teeth are found, four teeth have been reported in children as young as five months and as old as twenty months, eight teeth in children seven and twenty-four months, twelve teeth in children eleven and thirty months, and sixteen teeth in children eleven and thirty-seven months. The duration of the deciduous eruption period varies from less than one year to almost three years. For over 90 per cent of children the span of time within which the first dentition erupts is eighteen to thirty months. Instances are on record of children erupting seven teeth in 1.5 months, twelve teeth in six months, and twenty teeth in nine months.

10. The usual order of eruption for the deciduous teeth is incisors, first molars, canines, second molars. In greater detail, the characteristic eruptive sequence has been established as lower first incisors, upper first incisors, upper second incisors, lower second incisors, first molars (upper and lower), canines (upper and lower), lower second molars, upper second molars. It follows that the six erupted teeth of the typical child aged one year are the lower first incisors and the upper first and second incisors. Similarly, the sixteen erupted teeth of the typical child aged two years are the first and second incisors, the first molars and the canines. For about 95 per cent of children the first tooth to erupt is a lower first incisor. Occasionally eruption begins with an upper first incisor, upper second incisor or first molar. The third tooth to erupt is ordinarily an upper first incisor, but is an upper second incisor in approximately 20 per cent of infants and a lower second incisor in roughly 5 per cent. Additional exceptions to the predominant pattern include the eruption of first molars before second incisors, canines before second incisors, canines before first molars and second molars before canines. Obviously, when these exceptions are elaborated for specific teeth or tooth pairs, an extensive list of variations accrues.



Fig. 217. Average, maximum and minimum numbers of permanent teeth erupted in boys of specified chronological ages (excluding third molars). Data derived from examination of 237 grade school pupils. (Klein, H., and Cody: J. Am. Dent. A., vol. 26.)



Fig. 218. Average, maximum and minimum numbers of permanent teeth erupted in girls of specified chronological ages (excluding third molars). Data derived from examination of 2182 grade school pupils. (Klein, H., and Cody: J. Am. Dent. A., vol. 26.)

11. SEX. At all ages from nine months to two years teeth tend to erupt earlier in males than in females.

TABLE 341

## PERCENTAGE OF CHILDREN HAVING THE SPECIFIED CORRESPONDING PERMANENT TEETH ERUPTED\*

(From Klein et al., 1937)<sup>†</sup>

Age (Years) Last Birthday†		6		7		8		9		10		11		12		13		14		15	
Number of Cases		171	156	197	205	231	256	253	240	270	259	262	269	299	297	267	278	199	165	83	58
Sex	Boys	Girls		Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
	Girls	Boys		Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
Percent of Cases Having Designated Teeth Erupted																					
Upper Jaw	Central incisor.	14.9	26.3	54.3	70.1	90.0	94.1	98.4	99.6	100.0	99.6	100.0	100.0	100.0	99.8	100.0	100.0	100.0	100.0	100.0	100.0
	Lateral incisor.	2.6	3.5	15.2	22.3	43.5	63.5	80.2	93.7	95.9	94.2	96.7	98.1	98.7	98.5	99.4	98.7	98.7	98.8	97.6	96.7
	Canine.		1.3	0.8	0.7	1.3	2.1	5.3	8.5	15.6	35.1	40.8	66.4	69.4	84.8	90.6	93.7	93.2	95.8	96.4	98.3
	First premolar.		0.6	1.3	2.2	10.0	10.6	27.1	36.5	50.6	62.5	76.5	87.5	90.6	95.1	97.4	98.6	99.0	99.4	100.0	99.2
	Second premolar.	0.3	0.6	0.2	1.2	4.8	4.5	16.0	18.7	33.5	44.6	60.9	70.8	80.4	83.8	90.8	94.1	95.2	98.5	97.6	97.5
	First molar.	54.7	61.2	88.8	93.0	97.0	99.6	100.0	99.6	100.0	100.0	100.0	100.0	100.0	99.8	100.0	99.8	100.0	100.0	100.0	100.0
	Second molar.							0.4	0.4	2.6	6.0	17.0	25.6	45.5	57.4	73.2	79.9	84.7	90.6	87.9	91.7
Lower Jaw	Central incisor.	63.4	79.8	91.4	94.7	99.4	99.2	99.0	99.6	99.6	100.0	100.0	100.0	100.0	100.0	99.6	100.0	100.0	100.0	100.0	100.0
	Lateral incisor.	12.3	22.4	45.7	61.2	85.7	92.6	96.6	99.6	98.7	100.0	99.8	100.0	99.8	100.0	99.8	100.0	100.0	100.0	100.0	100.0
	Canine.	0.4	1.3	0.5	1.2	1.7	7.4	12.1	41.0	45.0	70.3	76.5	93.9	91.0	96.8	98.5	99.8	98.7	99.4	100.0	100.0
	First premolar.	0.3	0.6		1.5	2.8	5.9	16.6	32.5	42.8	55.6	72.9	86.2	85.1	94.3	96.8	98.0	98.2	99.1	98.8	100.0
	Second premolar.		1.0		0.7	3.0	4.3	9.7	17.5	29.6	36.1	53.8	66.1	72.2	79.6	84.3	89.2	92.7	97.6	93.4	95.0
	First molar.	65.5	76.9	91.9	93.7	98.9	99.7	100.0	100.0	100.0	100.0	99.6	99.6	99.6	99.8	99.8	100.0	99.5	100.0	100.0	100.0
	Second molar.							0.8	1.7	7.6	14.5	30.1	43.1	58.0	70.9	84.8	83.4	87.7	93.6	95.8	96.7

\* Four thousand and four hundred and sixteen boys and girls, Hagerstown, Md.

† The average age of the children included in each of the separate age groups falls approximately one half year above the age as given in the table, except for the 6 year old group, whose average age is at approximately 6½ years. This fact was considered throughout the analysis of the data.

**RACE.** While materials on Negro subjects are limited, it appears that there "no striking difference" in the average age of tooth eruption for white and Negro children. The few observations on American Indian children show apparently the same general eruption sequence as in white children, but suggest an earlier time of eruption.

**DIET AND DISEASE.** No association has been found between the age of eruption of deciduous teeth and early addition to the diet of vitamin B through the medium of brewers' yeast powder or a water-soluble extract of rice polishings. One investigation discovered "no difference in the age at eruption of teeth" between 150 children fed 110 USP units of vitamin D daily in irradiated evaporated milk and seventy children fed 1500 USP units daily in cod liver oil. In another study it was found that a group of fourteen male infants ingesting 300 to 400 USP units of vitamin D daily, and also having superior records for freedom from illness, erupted their incisor teeth at ages earlier than those reported in any other group. The age of tooth eruption in a small group of infants developing mild scurvy and mild (subclinical) rickets was found no different from that for healthy infants.

**PREMATURITY.** A limited number of observations tend to support the hypothesis that tooth eruption during the first postnatal year occurs later in infants born prematurely than in those born "at term."

TABLE 342

MEANS AND STANDARD DEVIATIONS OF AGE DISTRIBUTION OF ERUPTION OF CORRESPONDING PERMANENT TEETH

(Klein et al., 1937)<sup>8</sup>

<i>Teeth</i>	<i>Upper Jaw (Corresponding Teeth)</i>				<i>Lower Jaw (Corresponding Teeth)</i>			
	Mean (Years)		Stand. Dev. (Years)		Mean (Years)		Stand. Dev. (Years)	
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
Central incisor.....	7.49	7.20	0.75	0.75	6.50	6.19	0.74	0.70
Lateral incisor.....	8.62	8.15	1.10	0.94	7.64	7.31	0.80	0.75
Canine.....	11.80	11.05	1.42	1.37	10.70	9.85	1.15	1.15
First premolar.....	10.42	10.00	1.50	1.40	10.75	10.20	1.42	1.41
Second premolar.....	11.18	10.82	1.68	1.60	11.45	11.00	1.77	1.70
First molar.....	6.64	6.54	0.75	0.70	6.44	6.12	0.75	0.87
Second molar.....	12.70	12.40	1.18	1.40	12.20	11.90	1.20	1.55

TABLE 343  
AVERAGE AGE AND STANDARD DEVIATION IN YEARS OF ERUPTING PERMANENT TEETH  
(Hellman, 1943)<sup>7</sup>

Boys

Tooth	Upper				Lower			
	Right		Left		Right		Left	
	A	SD	A	SD	A	SD	A	SD
Central incisor . . . . .	7.32	±1.25	7.34	±0.89	6.29	±0.77	6.29	±0.77
Lateral incisor . . . . .	8.65	±1.27	8.55	±1.01	7.53	±1.09	7.56	±1.09
Canine . . . . .	12.08	±1.71	11.95	±1.62	11.04	±1.06	11.03	±1.06
Premolar 1 . . . . .	11.12	±1.23	11.22	±1.55	11.16	±1.29	11.01	±1.29
Premolar 2 . . . . .	12.35	±1.65	12.06	±1.58	12.31	±1.40	12.33	±1.40
Molar 1 . . . . .	6.72	±0.87	6.78	±0.80	6.84	±0.85	6.79	±0.85
Molar 2 . . . . .	12.88	±1.36	13.03	±1.59	12.55	±1.15	12.62	±1.15

Girls

Tooth	Upper				Lower			
	Right		Left		Right		Left	
	A	SD	A	SD	A	SD	A	SD
Central incisor . . . . .	7.25	±0.65	7.22	±0.62	6.23	±0.85	6.29	±0.85
Lateral incisor . . . . .	8.21	±1.02	8.12	±1.06	7.44	±0.76	7.42	±0.76
Canine . . . . .	11.73	±1.79	11.76	±1.99	10.22	±1.13	10.30	±1.13
Premolar 1 . . . . .	10.85	±1.11	10.81	±1.18	10.64	±1.03	10.68	±1.03
Premolar 2 . . . . .	12.05	±1.85	11.83	±1.58	11.70	±1.54	11.77	±1.54
Molar 1 . . . . .	6.89	±0.82	6.89	±0.81	6.64	±0.90	6.75	±0.90
Molar 2 . . . . .	13.00	±1.80	12.86	±1.67	12.60	±1.81	12.61	±1.81

TABLE 344

AVERAGE AGE AND STANDARD DEVIATION IN YEARS OF ERUPTING PERMANENT TEETH IN CHILDREN WITH NORMAL OCCLUSION

(Hellman, 1943)<sup>7</sup>

Boys

Tooth	Upper				Lower			
	Right		Left		Right		Left	
	A	SD	A	SD	A	SD	A	SD
Central incisor . . . . .	7.41	±0.84	7.63	±0.91	6.66	±0.82	6.46	±1.05
Lateral incisor . . . . .	8.98	±0.52	8.92	±0.45	8.03	±0.83	8.16	±0.96
Canine . . . . .	12.19	±1.61	12.20	±1.39	11.03	±1.01	11.14	±0.93
Premolar 1 . . . . .	11.13	±1.30	11.00	±1.19	10.89	±0.98	11.01	±1.12
Premolar 2 . . . . .	11.57	±1.41	11.80	±1.35	11.36	±1.03	11.41	±1.04
Molar 1 . . . . .	7.16	±1.05	7.16	±1.05	7.00	±0.82	7.08	±0.76
Molar 2 . . . . .	13.12	±1.10	13.33	±1.08	12.45	±0.59	12.73	±0.90
Molar 3 . . . . .	20.41	±2.75	20.57	±2.58	20.51	±2.33	20.34	±2.63

Girls

Tooth	Upper				Lower			
	Right		Left		Right		Left	
	A	SD	A	SD	A	SD	A	SD
Central incisor . . . . .	7.36	±0.63	7.80	±1.30	6.54	±0.85	6.69	±0.99
Lateral incisor . . . . .	8.76	±0.57	8.78	±0.62	7.97	±0.73	7.81	±0.70
Canine . . . . .	11.83	±1.21	11.70	±1.09	10.21	±1.10	10.40	±0.98
Premolar 1 . . . . .	10.88	±1.04	10.96	±1.00	10.57	±0.93	10.54	±0.73
Premolar 2 . . . . .	12.02	±1.54	11.86	±1.52	11.57	±1.32	11.68	±1.41
Molar 1 . . . . .	6.72	±1.01	6.69	±0.99	6.26	±1.00	6.45	±0.85
Molar 2 . . . . .	13.05	±1.44	12.92	±1.40	12.22	±1.26	12.26	±1.31
Molar 3 . . . . .	20.42	±1.76	20.37	±1.75	20.75	±2.70	20.09	±2.52

TABLE 345

ERUPTION TIME OF TEETH, SHOWING PROBABLE STATISTICAL ERROR AND THE VARIATION IN  
ERUPTION OF THE RIGHT AND LEFT SIDES

(Age in years)  
(Steggerda and Hill, 1942)<sup>13</sup>

Central Incisors

Race	Sex	Lower				Upper			
		No.	Right	No.	Left	No.	Right	No.	Left
Negro	Males	11	7.00 ± .17	10	6.90 ± .18	17	7.77 ± .16	17	7.77 ± .16
	Females	13	6.31 ± .21	12	6.25 ± .23	25	7.16 ± .12	21	7.16 ± .12
White	Males	40	6.93 ± .05	40	6.93 ± .05	47	7.87 ± .09	45	7.87 ± .09
	Females	37	6.60 ± .05	36	6.56 ± .06	32	7.56 ± .12	33	7.61 ± .12

Lateral Incisors

Negro	Males	15	8.00 ± .18	16	7.88 ± .17	20	8.50 ± .18	20	8.40 ± .18
	Females	22	7.18 ± .15	21	7.19 ± .15	32	8.22 ± .15	28	8.39 ± .15
White	Males	46	8.52 ± .08	43	8.49 ± .08	91	9.18 ± .06	87	9.14 ± .06
	Females	24	8.04 ± .12	21	7.86 ± .15	50	8.76 ± .09	43	8.79 ± .09

Canines

Negro	Males	38	11.03 ± .15	39	10.95 ± .14	41	11.81 ± .14	42	11.67 ± .14
	Females	43	9.70 ± .13	42	9.76 ± .14	45	10.44 ± .12	41	10.34 ± .12
White	Males	121	10.98 ± .07	121	10.89 ± .08	133	11.80 ± .07	131	11.85 ± .07
	Females	91	10.20 ± .08	88	10.23 ± .08	106	11.33 ± .08	103	11.48 ± .08

First Premolars

Negro	Males	38	10.92 ± .15	30	10.80 ± .16	33	10.88 ± .20	32	10.75 ± .20
	Females	45	10.33 ± .14	45	10.13 ± .12	45	10.11 ± .11	43	10.02 ± .11
White	Males	124	11.19 ± .09	127	11.11 ± .09	118	10.72 ± .09	117	10.72 ± .09
	Females	97	10.62 ± .09	95	10.64 ± .09	95	10.47 ± .10	94	10.57 ± .10

Second Premolars

Negro	Males	36	11.53 ± .15	36	11.42 ± .15	38	11.92 ± .15	35	11.91 ± .15
	Females	39	10.74 ± .13	42	10.79 ± .14	48	11.02 ± .12	44	10.91 ± .12
White	Males	125	11.91 ± .10	127	11.80 ± .10	119	11.51 ± .10	124	11.41 ± .10
	Females	90	11.49 ± .11	92	11.73 ± .12	101	11.25 ± .10	96	11.40 ± .10

First Molars

Negro	Males	13	6.85 ± .21	11	7.09 ± .20	7	6.57 ± .30	9	7.00 ± .30
	Females	15	6.33 ± .15	19	6.32 ± .15	8	7.13 ± .14	9	6.67 ± .14
White	Males	38	7.03 ± .05	42	6.93 ± .05	39	7.03 ± .04	40	7.05 ± .04
	Females	38	6.58 ± .05	35	6.60 ± .06	40	7.0 ± .11	35	6.94 ± .11

Second Molars

Negro	Males	47	12.30 ± .14	45	12.36 ± .15	39	12.49 ± .15	37	12.78 ± .15
	Females	50	11.50 ± .14	50	11.36 ± .14	45	11.82 ± .10	46	11.87 ± .10
White	Males	154	12.40 ± .06	162	12.41 ± .07	138	13.17 ± .08	144	12.93 ± .08
	Females	127	11.87 ± .08	126	11.85 ± .08	111	12.67 ± .09	110	12.56 ± .09

Third Molars

Negro	Males	4	18.25 ± .28	5	16.60 ± .31	2	18.50 ± .24	2	18.50 ± .24
	Females	31	18.26 ± .30	34	18.59 ± .34	3	17.25 ± .30	9	17.53 ± .30
White	Males	16	17.13 ± .12	14	17.71 ± .13	3	17.00 ± .32	3	17.33 ± .32
	Females	8	16.63 ± .26	9	16.78 ± .23	3	17.00 ± .32	3	17.00 ± .32

TABLE 346  
 DIMENSIONS (AVERAGE) OF DECIDUOUS TEETH  
 (Black, 1902)<sup>2</sup>  
 Upper Teeth

<i>Tooth</i>	<i>Over-all Length (mm.)</i>	<i>Length of Crown (mm.)</i>	<i>Length of Root (mm.)</i>	<i>Mesio- distal Diameter of Crown (mm.)</i>	<i>Mesio- distal Diameter of Neck (mm.)</i>	<i>Labio- lingual Diameter of Crown (mm.)</i>	<i>Labio- lingual Diameter of Neck (mm.)</i>
Central incisor.....	16.0	6.0	10.0	6.5	4.5	5.0	4.0
Lateral incisor.....	15.8	5.6	11.4	5.1	3.7	4.8	3.7
Cuspid.....	19.0	6.5	13.5	7.0	5.1	7.0	5.5
First molar.....	15.2	5.1	10.0	7.3	5.2	8.5	6.9
Second molar.....	17.5	5.7	11.7	8.2	6.4	10.0	8.3

Lower Teeth

Central incisor.....	14.0	5.0	9.0	4.2	3.0	4.0	3.5
Lateral incisor.....	15.0	5.2	10.0	4.1	3.0	4.0	3.5
Cuspid.....	17.0	6.0	11.5	5.0	3.7	4.8	4.0
First molar.....	15.8	6.0	9.8	7.7	6.5	7.0	5.3
Second molar.....	18.8	5.5	11.3	9.9	7.2	8.7	6.4

TABLE 347  
 DIMENSIONS OF PERMANENT TEETH  
 (Black, 1902)<sup>2</sup>  
 Upper Teeth

<i>Tooth</i>	<i>Over-all Length (mm.)</i>	<i>Length of Crown (mm.)</i>	<i>Length of Root (mm.)</i>	<i>Mesio- distal Diameter of Crown (mm.)</i>	<i>Mesio- distal Diameter of Neck (mm.)</i>	<i>Labio- lingual or Bucco- lingual Diameter (mm.)</i>	<i>Curve of the Gingival Line</i>
Central incisor:							
Average.....	22.5	10.0	12.0	9.0	6.3	7.0	3.0
Greatest.....	27.0	12.0	16.0	10.0	7.0	8.0	4.0
Least.....	18.0	8.0	8.0	8.0	5.5	7.0	2.0
Lateral incisor:							
Average.....	22.0	8.8	13.0	6.4	4.4	6.0	2.8
Greatest.....	26.0	10.5	16.0	7.0	5.0	7.0	4.0
Least.....	17.0	8.0	8.0	5.0	4.0	5.0	2.0
Cuspid:							
Average.....	26.5	9.5	17.3	7.6	5.2	8.0	2.5
Greatest.....	32.0	12.0	20.5	9.0	6.0	9.0	3.5
Least.....	20.0	8.0	11.0	7.0	4.0	7.0	1.0
First bicuspid:							
Average.....	20.6	8.2	12.4	7.2	4.9	9.1	1.1
Greatest.....	22.5	9.0	14.0	8.0	6.0	10.0	2.0
Least.....	17.0	7.0	10.0	7.0	4.0	8.0	0.0
Second bicuspid:							
Average.....	21.5	7.5	14.0	6.8	5.3	8.8	0.8
Greatest.....	27.0	9.0	19.0	8.0	6.5	10.0	1.5
Least.....	16.0	7.0	10.0	6.0	4.5	7.5	0.0
First molar:							
Average.....	20.8	7.7	13.2	10.7	7.5	11.8	2.2
Greatest.....	24.0	9.0	16.0	12.0	8.0	12.0	3.0
Least.....	17.0	7.0	10.0	9.0	7.0	11.0	1.0
Second molar:							
Average.....	20.0	7.2	13.0	9.2	6.7	11.5	1.6
Greatest.....	24.0	8.0	17.0	10.0	8.0	12.5	4.0
Least.....	16.0	6.0	9.0	7.0	6.0	10.0	0.0
Third molar:							
Average.....	17.1	6.3	11.4	8.6	6.1	10.6	0.7
Greatest.....	22.0	8.0	15.0	11.0	8.0	14.5	2.5
Least.....	14.0	5.0	8.0	7.0	5.0	8.0	0.0

Lower Teeth

Central incisor:							
Average.....	20.7	8.8	11.8	5.4	3.5	6.0	2.5
Greatest.....	24.0	10.5	16.0	6.0	5.0	6.5	3.0
Least.....	16.0	7.0	9.0	5.0	2.5	5.5	1.5
Lateral incisor:							
Average.....	21.1	9.6	12.7	5.9	3.8	6.4	2.5
Greatest.....	27.0	12.0	17.0	6.5	5.0	7.5	3.5
Least.....	18.0	7.0	11.0	5.0	3.0	6.0	2.0
Cuspid.....							
Average.....	25.6	10.3	15.3	6.9	5.2	7.9	2.9
Greatest.....	32.5	12.0	21.0	9.0	7.0	10.0	4.0
Least.....	20.0	8.0	11.0	5.0	3.0	6.0	2.0

TABLE 347—Continued

Lower Teeth

Tooth	Over-all Length (mm.)	Length of Crown (mm.)	Length of Root (mm.)	Mesio-distal Diameter of Crown (mm.)	Mesio-distal Diameter of Neck (mm.)	Labio-lingual or Bucco-lingual Diameter (mm.)	Curvature of the Gingival Line
First bicuspid:							
Average	21.6	7.8	14.0	6.9	4.7	7.7	0.8
Greatest	26.0	9.0	18.0	8.0	5.0	8.0	1.5
Least	18.0	6.5	11.0	6.0	4.5	7.0	0.5
Second bicuspid:							
Average	22.3	7.9	14.4	7.1	4.8	8.0	0.6
Greatest	26.0	10.0	17.5	8.0	6.5	9.0	2.0
Least	18.0	6.0	11.5	6.5	4.0	7.0	0.0
First molar:							
Average	21.0	7.7	13.2	11.2	8.5	10.3	1.1
Greatest	24.0	10.0	15.0	12.0	9.5	11.5	2.0
Least	18.0	7.0	11.0	11.0	7.5	10.0	0.0
Second molar:							
Average	19.8	6.9	12.9	10.7	8.1	10.1	0.2
Greatest	22.0	8.0	14.0	11.0	8.5	10.5	1.0
Least	18.0	6.0	12.0	10.0	8.0	9.5	0.0
Third molar:							
Average	18.5	6.7	11.8	10.7	8.3	9.8	0.2
Greatest	20.0	8.0	17.0	12.0	9.5	10.5	1.5
Least	16.0	6.0	8.0	8.0	5.0	9.0	0.0

TABLE 348

MAXIMUM WIDTHS AND VARIABILITIES OF UPPER CENTRAL AND LATERAL INCISOR TEETH  
(BOYS AND GIRLS, AGES 8 TO 14 YEARS)

(Young, 1932)<sup>19</sup>

	Maximum Width of Central Incisor (mm.)		Maximum Width of Lateral Incisor (mm.)	
	Boys	Girls	Boys	Girls
Mean mm.	8.61 ± 0.04	8.43 ± 0.04	6.55 ± 0.04	6.52 ± 0.04
S.D. (mm.)	0.51 ± 0.02	0.53 ± 0.03	0.54 ± 0.03	0.54 ± 0.03
Coeff. of V. (%)	5.96 ± 0.29	6.25 ± 0.34	8.08 ± 0.39	8.35 ± 0.45
No. of obs.	214	172	214	172

Dahlberg<sup>4</sup> found that 95 per cent of the maxillary first molars had well-developed cusps. The maxillary second molar presented much greater morphologic variation. Only 38 per cent of the ninety-two maxillary second molars studied had four well-developed cusps; 20 per cent showed a reduction in the size of the distolingual cusp; 42 per cent had a complete absence of the distolingual cusp.

Dahlberg also reported that 4 per cent of the median central incisors are shovel-shaped and that 12.8 per cent are semishovel-shaped. Approximately 2.4 per cent of the lateral incisors are shovel-shaped and 16.2 per cent are semishovel-shaped.

TABLE 349  
ASYMMETRY OF MESIODISTAL WIDTH  
(Ballard, 1944)<sup>1</sup>  
Maxillary Teeth

	<i>Number of Teeth Measured</i>	<i>Number Cases with Dis- crepancy</i>	<i>Per- centage</i>	<i>Dis- crepancy 0.25-0.50 mm.</i>	<i>Per- centage</i>	<i>Discrep- ancy of 0.50 mm. or More</i>	<i>Per- centage</i>
Central incisor . . . . .	999	123	12.3	28	2.8	95	9.5
Lateral incisor . . . . .	972	178	18.3	39	4.0	139	14.3
Cuspid . . . . .	868	109	12.5	30	3.4	79	9.1
First bicuspid . . . . .	914	112	12.2	31	3.3	81	8.8
Second bicuspid . . . . .	871	114	13.0	28	3.2	86	9.8
First molar . . . . .	988	144	14.5	24	2.4	120	12.1

Mandibular Teeth

Central incisor . . . . .	988	100	10.1	21	2.2	79	7.9
Lateral incisor . . . . .	989	117	11.8	35	3.5	82	8.3
Cuspid . . . . .	912	129	14.1	25	2.7	104	11.4
First bicuspid . . . . .	906	154	16.9	46	5.0	108	11.9
Second bicuspid . . . . .	836	97	11.6	24	2.8	73	8.7
First molar . . . . .	972	129	13.2	28	2.8	101	10.3

CONGENITALLY MISSING TEETH, PATTERNS AND COMBINATIONS

Brekhus and his co-workers<sup>3</sup> collected data from 11,487 patients at the dental clinics of the University of Minnesota during the two years 1941 to 1942. In this group 195 cases of congenitally missing teeth were found. This number only approximates the actual number of dental anomalies in the 11,487 patients. More females than males were studied. Most of the population were Caucasians. The average age of the 195 patients was 22.9 years; the median age was twenty-one.

The determination of the true incidence of congenitally missing teeth must be based upon the primary contact persons or index cases, referred to as p

siti. There were 178 propositi with congenitally missing teeth. The relative proportions of propositi with only one kind of missing tooth and with the various combinations do not differ significantly from those reported for all 4 cases.

TABLE 350  
NUMBER OF MISSING AND PEG-SHAPED TEETH IN 184 PERSONS  
(Brekhus et al., 1944)<sup>3</sup>

	Right								Left							
Number missing in upper.....	53	3	2	39	10	2	25	1	1	34	5	13	39	2	3	47
Teeth.....	8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
Number missing in lower.....	52	3	2	42	5	2	2	15	16	1	1	6	46	2	3	52

For the upper second incisors, the upper numbers represent the "pegs"; the lower, the missing teeth.

TABLE 351  
OBSERVED COMBINATIONS OF MISSING TEETH IN 184 PERSONS  
(Brekhus et al., 1944)<sup>3</sup>

Dental Combinations	Number of Cases				
	USI	2 Pm	3M	Misc.	Totals
Only one kind.....	60	22	4	6	92
USI, Misc.....	6	..	..	6	6
2Pm, Misc.....	..	5	..	5	5
3M, Misc.....	..	..	4	4	4
USI, 2Pm.....	7	7	..	..	7
USI, 2Pm, Misc.....	3	3	..	3	3
USI, 3M.....	30	..	30	..	30
USI, 3M, Misc.....	3	..	3	3	3
2Pm, 3M.....	..	15	15	..	15
2Pm, 3M, Misc.*.....	..	4	4	4	4
USI, 2Pm, 3M.....	6	6	6	..	6
USI, 2Pm, 3M, Misc.†....	9	9	9	9	9
Total cases.....	124	71	75	40	184

USI—upper second incisor; 2Pm—second premolar; 3M—third molar; Misc.—any other teeth. "Only one kind" indicates that only one type of tooth was absent.

\* Includes two extreme cases.

† Includes five extreme cases.

Of the 168 propositi, 111 were deficient in upper second incisors, sixty-six in second premolars, seventy in third molars, and thirty-seven in other (miscellaneous) teeth. The incidence of dental deficiencies among all patients (11,487),

TABLE 352

INCIDENCE OF COMBINATIONS OF MISSING TEETH BASED UPON 168 PROPOSITI  
(Brekhus et al., 1944)<sup>3</sup>

<i>Combinations of Abnormal Teeth</i>	<i>Number of Cases</i>	<i>Observed Incidence in Per Cent</i>	<i>Expected Incidence in Per Cent</i>	<i>Ratio: Obs. to Exp.</i>
USI, 2Pm.....	23	0.200	0.00555	36-1
USI, 3M.....	46	0.400	0.00588	68-1
2Pm, 3M.....	30	0.261	0.00350	75-0

USI—upper second incisor; PM—second premolar; 3M—third molar.

TABLE 353

NUMBER OF MISSING PERMANENT SECOND PREMOLARS AND RETAINED DECIDUOUS SEC  
MOLARS IN 153 PERSONS  
(Oliver et al., 1945)<sup>14</sup>

	<i>Missing Permanent in Quadrants</i>		<i>Retained Deciduous in Quadrants</i>	
	Right	Left	Right	Left
Upper.....	62	77	23	17
Lower.....	87	104	35	40
Totals.....	330		115	

TABLE 354

PROPORTION OF PERSONS RETAINING DECIDUOUS TEETH OR SPACES IN SECOND PREMOLAR AR  
(Oliver et al., 1945)<sup>14</sup>

	<i>Deciduous Teeth</i>			
	Present	Absent, but Space Ample	Absent, with Slight Space	Absent, with No Space
Number of persons.....	64	32	21	36
Percentage.....	41.8	20.9	13.7	23.5

as measured by the propositi, is, therefore, 1.5 per cent. The incidence of missing and abnormal upper second incisors among the patients of the clinic is 0.90 per cent; of missing second premolars, 0.575 per cent; of missing third molar 0.609 per cent; and of missing miscellaneous teeth, 0.322 per cent.

Oliver<sup>14</sup> reports from his records 427 persons having congenital anomalies of the teeth. Of these, 153 failed to develop a total of 330 second molars. Tables 353 and 354 show the number lacking. In this same group sixty-four persons had one or more deciduous second premolars at the time they were examined, the number of retained deciduous teeth being 115.

## WEIGHTS

RELATIVE WEIGHTS OF ENAMEL TO DENTIN AND CEMENTUM. From about 10,000 teeth extracted in various localities in Indiana, Cheyne and Oba<sup>4</sup> selected 759 sound specimens, representing the thirty-two permanent types, for

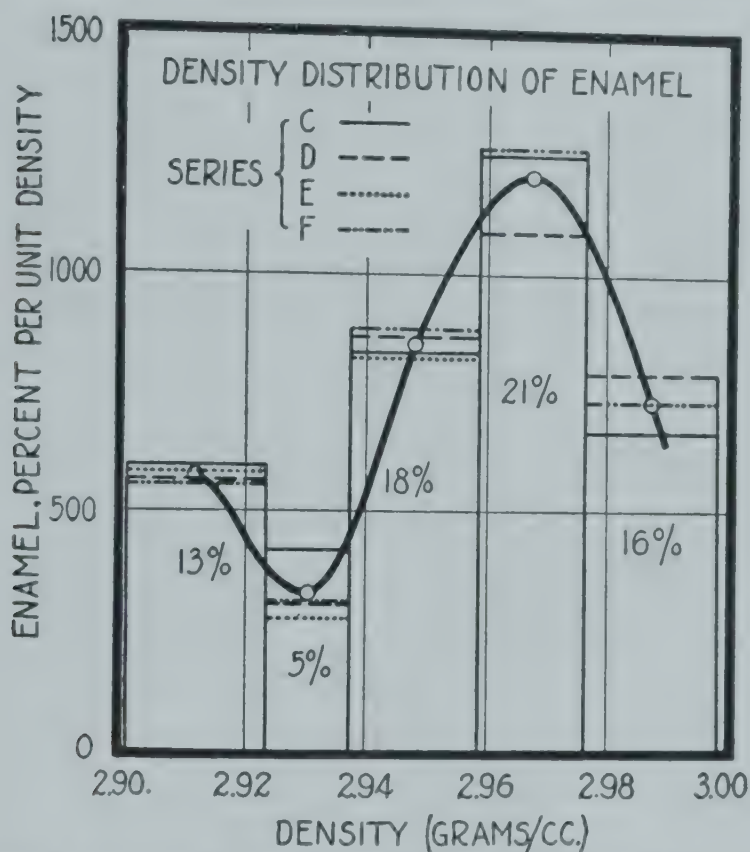


Fig. 219. Density distribution of enamel sample (curve indicates average of four determinations; shows little material with density 2.92-2.94. The two maxima at 2.91 and 2.97 respectively, suggest two varieties of enamel. (Manly, R. S., et al.: *J. Dent. Res.*, vol. 18.)

weighing. Only those teeth were used which conformed to normal anatomic form and exhibited a minimum amount of wear. In all cases the roots were completely formed. Teeth with excessive amounts of secondary cementum were not used. Before being weighed, each tooth was carefully cleaned by scraping adherent soft tissues, calculus and other debris. At no time after extraction were they allowed to dry out. After cleaning, all teeth were placed in a humidifier at constant temperature. Quantitative weighings were made at intervals in tight weight bottles until each tooth reached equilibrium. Enamel was separated from dentin and cementum by the method of Manly and Hodge.<sup>12</sup>

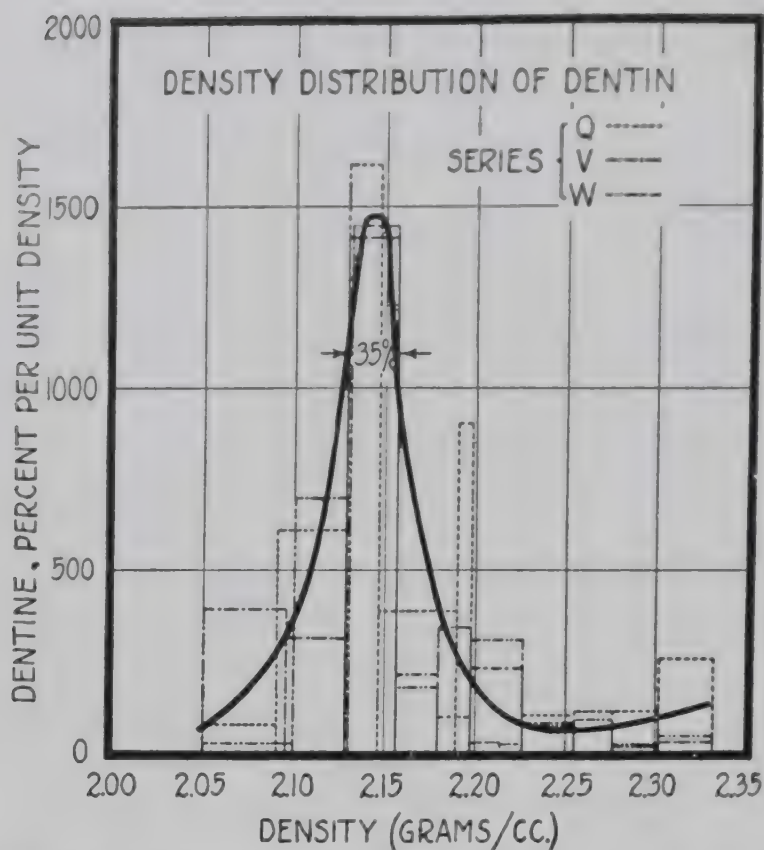


Fig. 220. Triplicate determination of density distribution of dentin from noncarious teeth. More than third of dentin has density between 2.13 and 2.16, even though density range is 2.03-2.35. (Manly, R. S., et al.: *J. Dent. Res.*, vol. 18.)

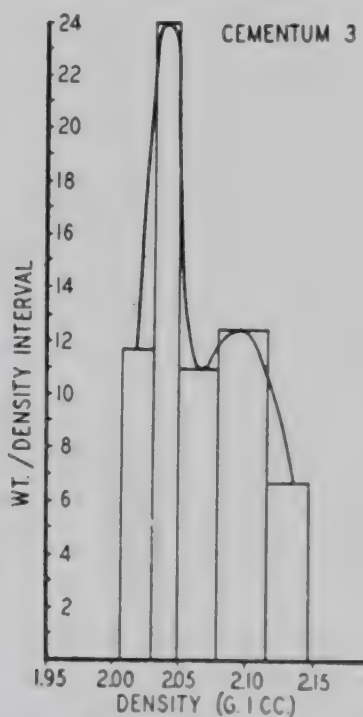


Fig. 221. Density distribution of hypercementosed root tips. Cementum exhibits a sharp maximum at 2.03-2.05. Density maximum at 2.10 is probably that of root dentin. (Manly, R. S., et al.: *J. Dent. Res.*, vol. 18.)

TABLE 355  
AVERAGE WEIGHTS OF PERMANENT TEETH  
(Cheyne and Oba, 1943)<sup>4</sup>

<i>Tooth</i>	<i>Number of Teeth</i>	<i>Average Moist Weight (Grams)</i>	<i>Range</i>	<i>Standard Deviation</i>
Upper:				
1st incisor.....	51	1.1917	0.8652-1.6211	0.1726
2d incisor.....	51	0.8171	0.5208-1.1655	0.1190
Canine.....	51	1.2821	0.8526-1.8435	0.2188
1st premolar.....	51	1.2283	0.8970-1.7556	0.2334
2d premolar.....	54	1.1266	0.8726-1.3845	0.1405
1st molar.....	40	2.4830	1.9840-3.1845	0.3020
2d molar.....	54	2.1780	0.4100-2.9125	0.3324
3rd molar.....	53	1.7323	1.0733-2.4395	0.3205
Total.....	405	12.0391		
Lower:				
1st incisor.....	55	0.5494	0.2995-0.7827	0.0810
2d incisor.....	49	0.6326	0.4429-0.9290	0.0854
Canine.....	41	1.0945	0.7495-1.6194	0.1869
1st premolar.....	49	0.9712	0.7326-1.3882	0.1443
2d premolar.....	54	1.0934	0.7946-1.5124	0.1550
1st molar.....	38	2.3175	1.7770-3.1788	0.3276
2d molar.....	42	2.2656	1.5054-2.9000	0.3184
3rd molar.....	26	1.9891	1.5136-2.8132	0.2887
Total.....	354	10.9133		
Both arches.....	759	22.9524		

TABLE 356

RELATIVE WEIGHTS OF ENAMEL TO DENTIN AND CEMENTUM  
(Cheyne and Oba, 1943)<sup>4</sup>

<i>Tooth</i>	<i>Enamel</i>	<i>Per Cent</i>	<i>Dentin and Cementum</i>	<i>Per Cent</i>	<i>R</i>
Upper:					
1st incisor . . . . .	0.2624	22.02	0.9293	77.98	3.
2d incisor . . . . .	0.1740	21.30	0.6431	78.70	3.
Canine . . . . .	0.2822	22.01	0.9999	77.99	3.
1st premolar . . . . .	0.2785	22.67	0.9498	77.33	3.
2d premolar . . . . .	0.2189	19.43	0.9077	80.57	4.
1st molar . . . . .	0.5907	23.79	1.8923	76.21	3.
2d molar . . . . .	0.4461	20.48	1.7319	79.52	3.
3rd molar . . . . .	0.4036	23.30	1.3287	76.70	3.
Total . . . . .	2.6564	22.06	9.3827	77.94	3.
Lower:					
1st incisor . . . . .	0.0696	12.67	0.4798	87.33	6.
2d incisor . . . . .	0.1191	18.83	0.5135	81.17	4.
Canine . . . . .	0.1362	12.44	0.9583	87.56	7.
1st premolar . . . . .	0.1647	16.96	0.8065	83.04	4.
2d premolar . . . . .	0.3234	29.58	0.7700	70.42	2.
1st molar . . . . .	0.5068	21.87	1.8107	78.13	3.
2d molar . . . . .	0.5913	26.10	1.6743	73.90	2.
3rd molar . . . . .	0.5201	26.15	1.4690	73.85	2.
Total . . . . .	2.4312	22.28	8.4821	77.72	3.
Both arches . . . . .	5.0876	22.17	17.8648	77.83	3.

The per cent of each fraction as well as the ratio of one to the other, assuming enamel a figure of 1, are also expressed in this table.

TABLE 357

SPECIFIC WEIGHT AND INDEX OF REFRACTION OF DENTAL TISSUES

	<i>Specific Weight</i>	<i>Index of Refraction</i>
Enamel:		
Normal . . . . .	2.92	1.619
Mineralized . . . . .	3.02	1.619
Calcined . . . . .	3.12	1.632
Dentin:		
Normal . . . . .	2.51	1.568
Mineralized . . . . .	3.00	1.589
Calcined . . . . .	3.13	1.642
Cementum:		
Normal . . . . .	2.47	1.552
Mineralized . . . . .	3.00	1.590
Calcined . . . . .	3.17	1.643

The species of animal furnishing the teeth, and the number of samples and observations were not stated.

"Mineralized" is material boiled in glycerol containing 6 per cent potassium hydrate remove organic constituents.

"Calcined" is applied to material after it has been mineralized, heating at 900° C.

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## Chapter 66

### CHEMISTRY OF TEETH

TABLES 358 and 359 give analyses of enamel and dentin from sound human teeth. Table 360 gives an analysis of whole, sound human teeth.

TABLE 358

CALCIUM, MAGNESIUM, PHOSPHORUS AND CARBON DIOXIDE (FROM CARBONATE) OF HUMAN ENAMEL, DENTIN AND BONE IN PERCENTAGE OF WHOLE TISSUE ON "DRY" BASES\*

	<i>Enamel</i>	<i>Dentin</i>	<i>Bone</i>
Calcium.....	35.77	24.78	23.84
Magnesium.....	0.27	0.79	0.30
Phosphorus.....	17.43	12.34	10.41
Carbon dioxide.....	2.97	3.06	3.81

\* Water which is not removed at about 100°C. was included in the weight from which calculations were made. The percentage of such combined water was estimated to be approximately 2 for enamel, 8 for dentin, and 5 for bone. The value for enamel was recalculated from the proportion of enamel (previously dried at 105°C.) lost by incineration. The total loss on incineration minus the organic matter and carbon dioxide lost as a result of treatment with nitric acid during ashing, was regarded as representing the water present.

TABLE 359

CALCIUM, MAGNESIUM, PHOSPHORUS AND CARBON DIOXIDE (FROM CARBONATE) IN ENAMEL AND DENTIN

(Armstrong and Brekhuis, 1937, 1938)<sup>2</sup>

	<i>Constituents in Mean Percentage of Whole Tissue on "Dry" Basis*</i>		<i>Constituents in Percentage of Mineral Matter</i>	
	<i>Enamel</i>	<i>Dentin</i>	<i>Enamel†</i>	<i>Dentin†</i>
Calcium.....	35.41	26.18	36.41	33.69
Magnesium.....	0.30	0.83	0.24	0.89
Phosphorus.....	17.45	12.74	17.39	15.78
Carbon dioxide.....	3.00	3.57	3.07	4.76

\* See footnote, Table 358.

† The enamel and dentin for these analyses were prepared from pooled sound teeth.

TABLE 360

## ANALYSES OF WHOLE, SOUND TEETH

(LeFevre and Hodge, 1937)<sup>4</sup>

	<i>Range of Constituents in Percentage on "Dry" and Fat-Free Basis*</i>	<i>Constituents in Mean Percentage†</i>
Calcium.....	26.05-30.07	35.1
Magnesium.....	0.31-0.89	0.49
Phosphorus.....	12.96-19.71	16.8
Carbon dioxide.....	2.14-3.13	3.44
Water.....		8.71
Inorganic.....		84.7

\* See footnote, Table 358.

† In the last column the value for water represents the loss in weight after heating the teeth at 96 C. for seven days. The weight resulting after this treatment is the dry weight. The value for inorganic matter as a whole is given as percentage of the dry weight; inorganic constituents as percentage of inorganic weight.

LeFevre and Hodge<sup>4</sup> analyzed 110 teeth from ten subjects and summarized the data they obtained as follows:

Teeth of adults show wide limits of variation in moisture content: namely, from 4.58 to 9.98 (average, 9.98); in carbon dioxide content, from 2.99 to 4.03 (average, 3.45). The limits of variation for residue solution number and inorganic residue are relatively narrower, from 11.3 to 14.0 (average, 12.6) and 78.7 to 90.1 (average, 84.8), respectively. The values for calcium, phosphorus and hence the calcium: phosphorus percent ratio are relatively constant, calcium ranging from 33.6 to 36.8 (average, 35.2), phosphorus from 16.0 to 17.4 (average 16.8), and the ratio from 2.02 to 2.18 (average, 2.10). Briefly, the data may be represented as the average percentage, plus or minus the standard deviation, as follows: moisture,  $8.98 \pm 2.23$ ; inorganic residue,  $84.8 \pm 2.56$ ; calcium,  $35.2 \pm 0.76$ ; phosphorus,  $16.8 \pm 0.36$ ; calcium: phosphorus percent ratio,  $2.10 \pm 0.03$ ; carbon dioxide,  $3.45 \pm 0.26$ ; and the residue solution number,  $84.8 \pm 0.63$ .

Deciduous teeth have more moisture, less inorganic residue, calcium and phosphorus, and about the same carbonate content and residue solution number as permanent teeth.

There is little difference, except in moisture content, between carious and sound teeth, and little evidence of change in composition with age, and little chemical difference between teeth from males and those from females.

Armstrong and Brekhus<sup>2</sup> found that the pooled enamel separated from the crowns of three sound deciduous teeth, the roots of which had been physiologically resorbed, contained 0.0072 per cent fluorine. Three samples of dentin pooled from twenty-six sound teeth contained 0.0169, 0.0172 and 0.0167 per cent fluorine. They also found the fluorine content of enamel of sound permanent teeth (forty-two specimens) to have a range of 0.0073 to 0.0167 per cent; mean, 0.0111; sigma, 0.00186.

TABLE 361  
FLUORINE CONTENT PER CENT OF ENAMEL AND DENTIN OF MOTTLED TEETH  
(Armstrong and Brekhus, 1938)<sup>2</sup>

Patient	Tooth	Degree of Caries	Fluorine	
			Enamel	Dentin
A .....	5	None	0.0254	0.037
			0.0246	0.037
			0.0250	0.042
B .....	5	None	0.0245	0.041
	2/2	Severe	0.0357	
	3/3	Severe	0.0333	
	1	Moderate	0.0361	
	1	Questionable	0.0343	

TABLE 362  
FLUORINE CONTENT OF DENTIN AND ENAMEL TO DENTAL CARIES  
(Ockerse, 1943)<sup>6</sup>

Area	Fluorine, Parts per Million	
	Enamel	Dentin
Low caries .....	445	775
High caries .....	153	258

TABLE 363  
COMPOSITION OF ENAMEL OF SOUND AND CARIOUS TEETH  
(Armstrong, 1944)<sup>1</sup>

Constituents	Enamel of Sound Teeth			Enamel of Carious Teeth		
	Mean Per Cent	Standard Deviation Per Cent	Number of Analyses	Mean Per Cent	Standard Deviation Per Cent	Number of Analyses
Calcium .....	35.35	0.977	43	35.63	0.638	15
Phosphorus .....	17.43	0.360	43	17.21	0.145	15
Magnesium .....	0.30	0.041	34	0.32	0.026	15
Carbonate (CO <sub>2</sub> ) .....	3.00	0.187	41	3.01	0.129	14

TABLE 364

FLUORINE CONTENT OF ENAMEL AND DENTIN OF SOUND AND CARIOUS TEETH  
(Armstrong, 1944)<sup>1</sup>

<i>Tissue</i>	<i>Mean Fluorine Content Per Cent</i>	<i>Standard Deviation Per Cent</i>	<i>Number of Analyses</i>
Enamel of sound teeth.....	0.0111	0.0020	50
Enamel of carious teeth.....	0.0069	0.0011	50
Dentin of sound teeth.....	0.0169	.....	*
Dentin of carious teeth.....	0.0158	.....	*

The samples of dentin were prepared by pooling 50 mg. quantities of dentin from each twenty-six teeth.

TABLE 365

FLUORINE CONTENT OF ENAMEL AND DENTIN OF MOTTLED TEETH  
(Armstrong, 1944)<sup>1</sup>

<i>Mottled Teeth</i>	<i>Enamel Fluorine (Per Cent)</i>	<i>Dentin Fluorine (Per Cent)</i>
Severely mottled— <i>Patient A</i> :		
Upper right second bicuspid.....	0.0250	0.0375
Upper left second bicuspid.....	0.0248	0.0415
Mildly mottled— <i>Patient B</i> :		
Upper right and left second incisor.....	0.0357	.....
Upper right and left cuspids.....	0.0333	0.0504*
Upper left first incisor.....	0.0361	.....
Upper right first incisor.....	0.0343	.....

\* Pooled dentin of teeth of Patient B.

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## Chapter 67

### RELATIVE HARDNESS OF TEETH

THE HARDNESS of enamel and dentin, as compared with steel and brass shown in Figures 222, 223, 224, 225, and 226.\*

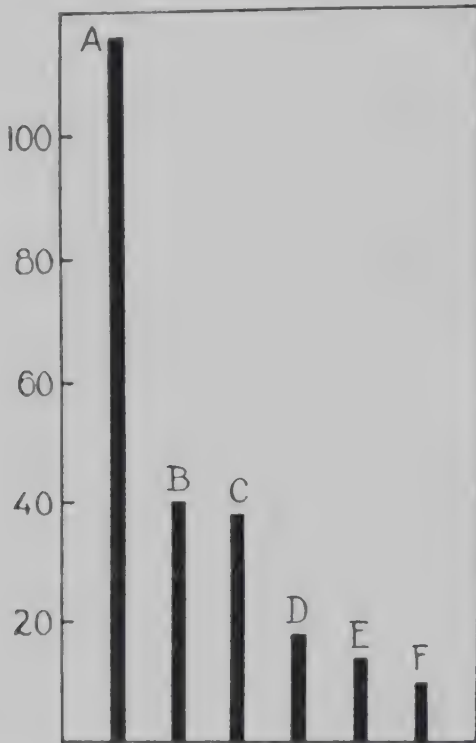


Fig. 222

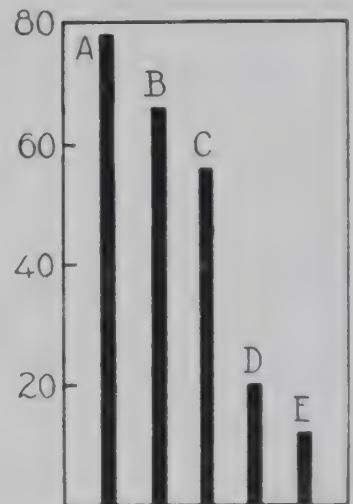


Fig. 223

Fig. 222. Relative hardness of: A, tempered tool steel; B, artificial (porcelain) crown; C, anterior labial enamel; D, mild steel; E, brass; F, dentin (using Monotron hardness test) (Hodge, H. C.: J. Dent. Res., vol. 15.)

Fig. 223. Relative hardness of: A, tempered steel; B, anterior labial enamel; C, enamel unerupted third molar; D, dentin; E, brass (using steel ball of Rockwell hardness test) (Hodge, H. C.: J. Dent. Res., vol. 15.)

\* Hodge, H. C.: J. Dent. Res., 15:271, 1935-36.

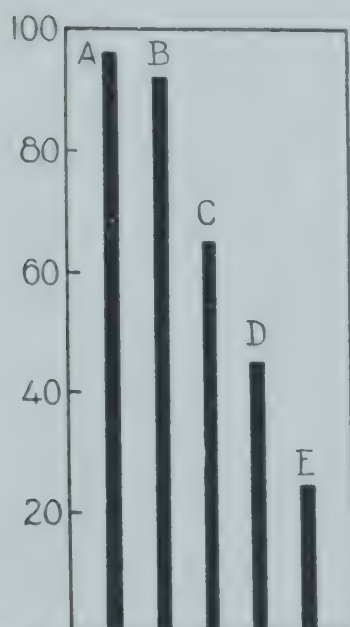


Fig. 224. Relative hardness of: *A*, tempered tool steel; *B*, anterior labial enamel; *C*, enamel unerupted third molar; *D*, dentin; *E*, brass (using Shore scleroscope hardness tester). (Hodge, H. C.: *J. Dent. Res.*, vol. 15.)

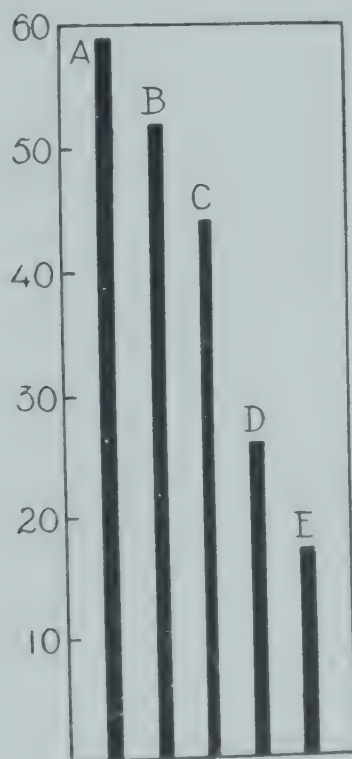


Fig. 225. Relative hardness of: *A*, steel; *B*, anterior labial enamel; *C*, enamel of unerupted third molar; *D*, dentin; *E*, brass (using Herbert pendulum hardness tester). (Hodge, H. C.: *J. Dent. Res.*, vol. 15.)

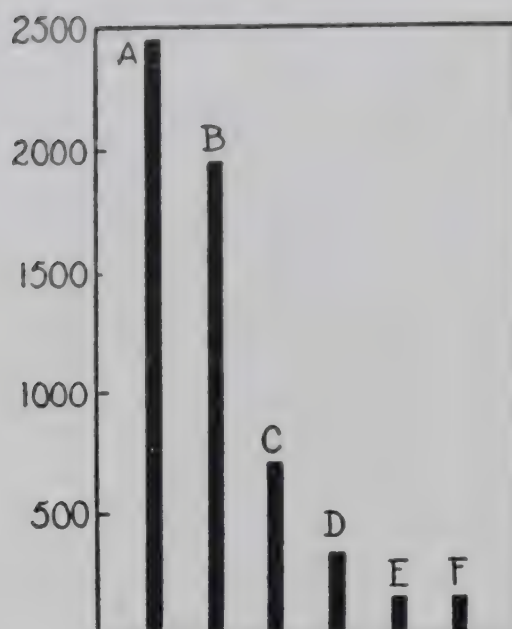


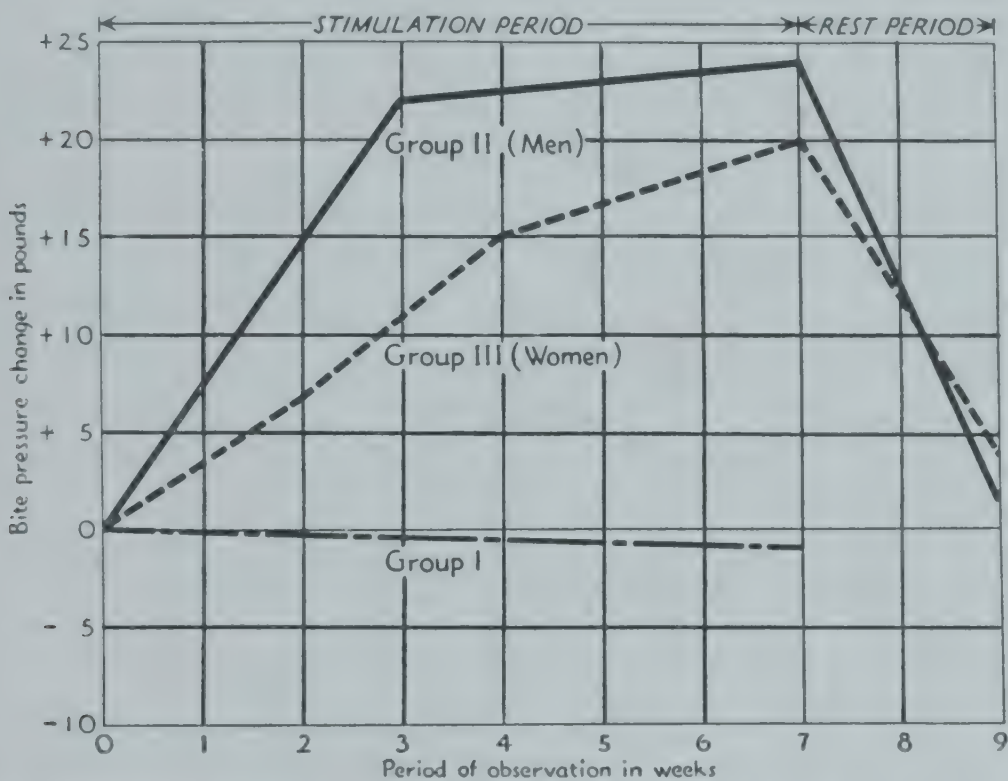
Fig. 226. Relative hardness of: *A*, tempered steel; *B*, anterior labial enamel; *C*, enamel of unerupted third molar; *D*, dentin; *E*, amalgam filling; *F*, brass (using microcharacter). (Hodges H. C.: J. Dent. Res., vol. 15.)

## Chapter 68

### MASTICATION

#### BITE PRESSURES

FORCE, expressed in pounds, with which the jaws may be closed on an object varies greatly among different persons. In tests made on 1000 young adults, the average force was 171 pounds on molars, considerably less on bicuspids and incisors.



227. Comparative results of muscle stimulation. (Brekhus, P. J., et al.: *J. Dent. Res.*, vol. 20.)

Tests of persons of various ages show the following averages:

Permanent first molars:	8 years.....	35 pounds
	12 years.....	75 pounds
	18 years.....	140 pounds
	Adults.....	175 pounds

A considerable number of young adults have registered 350 pounds.

TABLE 366  
STRENGTH OF BITE  
(Brekhus et al., 1941)<sup>1</sup>

	<i>Athletes</i> 108 Cases	<i>Dental</i> <i>Students</i> 108 Cases	<i>Difference</i>
Average age, years . . . . .	21	23	2
Average height, inches . . . . .	72	69	3
Average weight, pounds . . . . .	176	158	18
Average bite pressure, pounds . . . . .	126	125	1
Mean variant from average bite, pounds . . . . .	23.87	23.09	0.78

TABLE 367  
STATISTICS OF BITE PRESSURE IN POUNDS  
(Brekhus et al., 1941)<sup>1</sup>

<i>Group</i>	<i>Number</i>	<i>Elapsed Time</i> <i>in Days*</i>	<i>Group</i> <i>Average</i>	<i>Group Stand</i> <i>Deviation</i>
Males not exercised . . . . .	62	0	135	28
		50	136	23
Males exercised 50 days . . . . .	46	0	118	27
		21	140	28
		50	142	29
		50 + 14†	119	24
Females exercised 50 days . . . . .	20	0	79	17
		14	86	17
		28	94	18
		50	99	24
		50 + 14†	83	21

\* That is, from day of "original bite" determination which initiated the observation period.

† After fourteen day rest period.

Worner and Anderson,<sup>4</sup> who used a hydraulic gnathodynamometer capable of measuring the biting force between individual opposing teeth, also observed biting force to increase with age. The least biting force was exerted by the

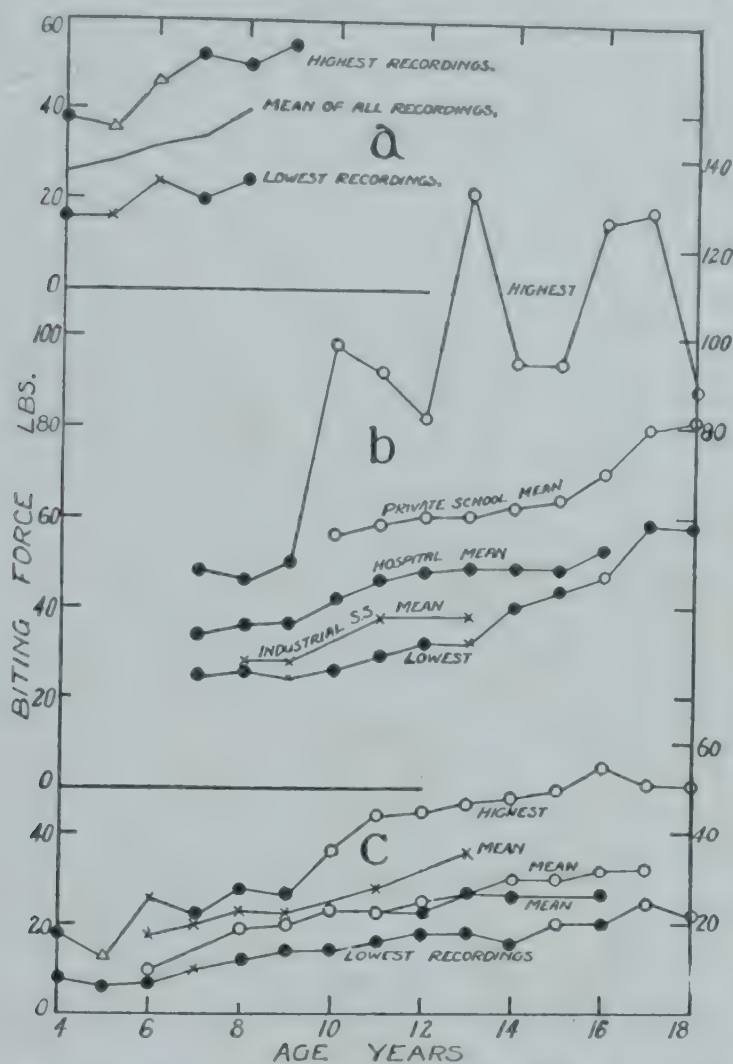


Fig. 228. Biting force registrations for girls at different ages. (a) Second deciduous molars; (b) first permanent molars; (c) central incisors; dental hospital patients; O, private boarding school scholars;  $\Delta$ , pupils of state school in residential suburb; X, pupils of state school in inner industrial suburb. (Worner, H. K., and Anderson.)

lateral (second) incisors, followed by the first incisors, cuspids, first and second cuspids and the first permanent molars. Data on the second molar varied, probably because of the incomplete eruption of this tooth in all subjects.

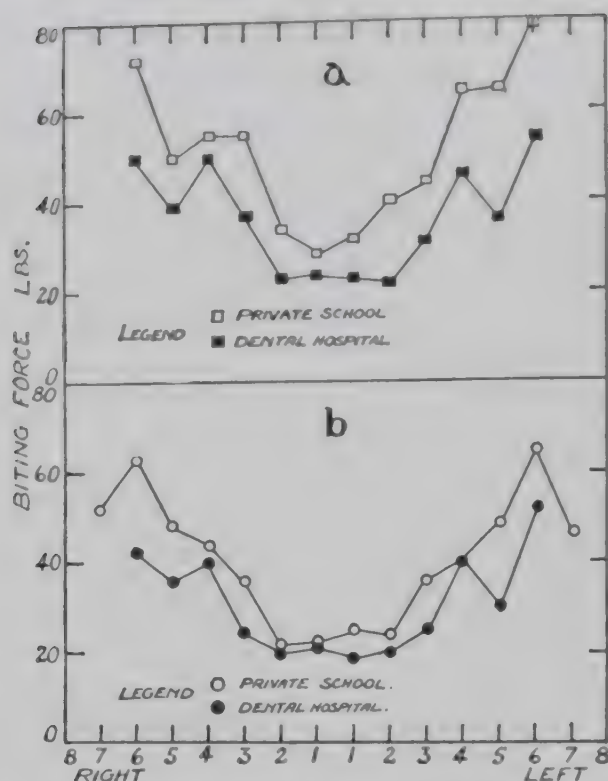


Fig. 229. Biting force charts of 12-year-old girls at a private boarding school and Dental Hospital of Melbourne. (a) Girls with highest registrations; (b) girls with charts closely approximating the average figures for their age group. (Worner, H. K., and Anderson.)

### CHEWS PER MEAL

Dahlberg<sup>2</sup> studied the chews per meal, using material obtained in a home for unmarried mothers (thirty-three women eighteen to twenty-five years of age).

To obtain a control, the number of mastications was ascertained by counting as well as by the automatic apparatus. It turned out that the average number of mastications was higher when registered by the apparatus than by counting. The reason must be that the apparatus registers small and quick movements of the lower jaw which cannot be observed at counting. The difference, however, in the number of mastications arrived at by counting and automatic registering is not significant.

On an average, the persons under investigation used  $420 \pm 26$  chews (see Table 368) when consuming a test meal. The standard deviation is  $\pm 111$  mastications, meaning that some persons chewed the meal with 100 mastications only, while others used over 700. This variation in number coincides with the well-known fact that some people chew carelessly, while others chew thoroughly.

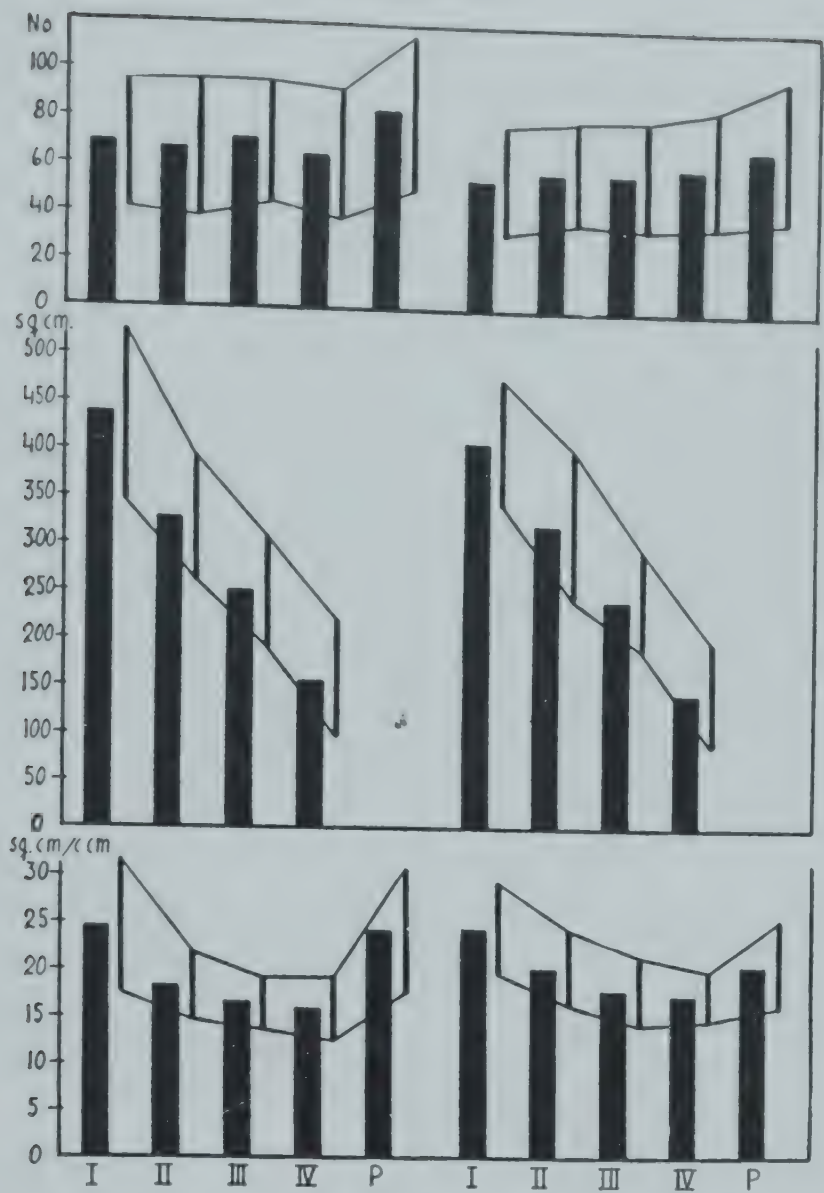


Fig. 230. At the top, the number of chews; in the middle, the occluding surface; at the bottom, mastication coefficients, for men (to the left) and women (to the right) with different sets of natural teeth (groups I-IV) and with prostheses (P). The black columns give the means and the vertical lines the standard deviation. I, Extremely good sets of teeth; II, good; III, fair; IV, extremely poor. (Dahlberg, B.)

TABLE 368  
NUMBER OF CHEWS WHEN EATING A STANDARD MEAL  
(Dahlberg, 1946)<sup>2</sup>

	Number	$M \pm \epsilon(M)$	$\sigma$
Group I (calculated with apparatus):			
st test.....	18	$416.89 \pm 26.29$	111.53
d test.....	18	$427.28 \pm 26.20$	111.15
Group II (calculated by direct observation):			
st test.....	15	$332.87 \pm 20.43$	79.13
d test.....	14	$366.79 \pm 24.43$	91.39

$M \pm \epsilon(M)$  = Mean  $\pm$  standard error of the mean.  
 $\sigma$  = Standard deviation.

TABLE 369

NUMBER OF CHEWS WHEN EATING A STANDARD MEAL: GOOD TEETH AND POOR TEETH  
(Dahlberg, 1946)<sup>2</sup>

	1st Test		2d Test	
	Number	M ± $\epsilon$ (M)	Number	M ± $\epsilon$ (M)
Group I: Good teeth.....	15	376.47 ± 30.43	14	404.21 ± 32
Group II: Poor teeth.....	18	380.56 ± 23.11	18	398.17 ± 21
Total.....	33	378.70 ± 18.41	32	400.81 ± 18

M ±  $\epsilon$ (M) = Mean ± standard error of the mean.

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4. Worner, H. K., and Anderson: Australian J. Dentistry, 48:1, 5, 1944.

# Chapter 69

## SALIVA

### RATE OF FLOW

FIGURES ON the rate of flow of saliva (milliliter per time unit) in man are not obtainable under natural conditions. The conscious participation of the subject produces variables which cannot be estimated or for which corrections cannot be calculated.

Salivary flow of a single gland or of a pair of glands (sublingual, submaxillary or parotid) has not been measured. Figures for salivary flow represent total salivary output for a given time under certain conditions. A common distinction between "resting saliva" and "activated saliva." "Activated saliva" is produced under some deliberate stimulus olfactory, gustatory, mechanical (e. g., chewing paraffin). "Resting saliva" is produced without deliberate stimulus, though it is probably impossible to eliminate psychic stimuli, conscious or subconscious.

The data obtained on salivary flow in man vary greatly among different persons and for the same person at different times. Brown and Klotz<sup>4</sup> divided their subjects into three groups: high, medium and low producers of saliva. Though there are borderline cases when the assignment of an individual to a group is arbitrary, this classification broadly reflects real and relatively constant differences between persons on the basis of salivary flow. Becks<sup>2</sup> and Wainwright<sup>10</sup> divided their subjects into Group I, with a maximum rate of flow up to 20 ml. per hour, and Group II, with higher rates of flow. Most borderline cases were deliberately excluded in these studies.

TABLE 370  
LOWEST AND HIGHEST ACTIVATED RATES OF FLOW OF SALIVA\*  
(Wainwright, 1939)<sup>10</sup>

Group	1934		1937		Total	
	1	2	3	4	5	6
	1 Hour Samples Cc./Hr.	15 Minute Samples Cc./Hr.	1 Hour Samples Cc./Hr.	15 Minute Samples Cc./Hr.	1 Hour Samples Cc./Hr.	15 Minute Samples Cc./Hr.
Low	38.5- 99.0	32.0-120.0	48.0- 83.0	46.0-104.0	38.5- 99.0	32.0-120.0
Medium	132.0-155.5	114.0-170.0	130.0-171.0	100.0-192.0	130.0-171.0	100.0-192.0
High	178.0-310.5	140.0-336.0	203.0-277.0	156.0-328.0	178.0-310.5	140.0-336.0

\* Calculated from Brown and Klotz values and recorded as cubic centimeters per hour.

Becks found 14 cc. of saliva per hour to be the average resting value subjects with a low rate of flow, as compared to 39.9 cc. per hour in subjects with a high rate of flow.

TABLE 371

COMPARISON OF RATES OF FLOW OF RESTING AND ACTIVATED SALIVAS  
(Becks and Wainwright, 1939)<sup>2, 10</sup>

	<i>Range</i>	<i>Average</i>
Group I:*		
Age.....	12-63	26.7
Resting saliva, cc./hr.....	2.5-15.8	9.0
Paraffin-activated saliva		
450 chews, cc./hr.....	54.9-190.1	103.0
Percentage of change from resting value..	477.3-2952.0	1185.0
Group II:†		
Age.....	6-35	19.1
Resting saliva, cc./hr.....	24.4-66.6	39.7
Paraffin-activated saliva:		
450 chews, cc./hr.....	38.0-187.0	89.2
Percentage of change from resting value..	32.3-311.2	128.8

\* Lowest rates of flow of resting saliva of thirty persons.

† Highest rates of flow of resting saliva of thirty persons.

TABLE 372

RATE OF FLOW OF CONTINUOUSLY ACTIVATED SALIVA  
(Wainwright, 1939)<sup>10</sup>

	<i>Range</i>	<i>Average</i>
Group I:*		
Range in cc./hr.†.....		84.0
Fluctuation:		
Cc./hr.....	12.5-115.9	43.4
Percentage.....	17.7-156.2	68.8
Group II:‡		
Range in cc./hr.....		86.3
Fluctuation:		
Cc./hr.....	16.9- 82.4	42.5
Percentage.....	39.6-161.5	73.9

\* Lowest rates of flow of resting saliva of thirty persons.

† From eight successive samples, 450 chews each, average time of collection for each sample 6 to 8 minutes.

‡ Highest rates of flow of resting saliva of thirty persons.

## CHEMISTRY

The tables which follow give the concentrations of chemical components of saliva, including solids, organic substances, ash, chlorides, sodium chloride, phosphorus, calcium, potassium, magnesium, sulfur, sulfocyanate,  $\text{HCO}_3$ , total nitrogen, ammonia nitrogen, amino acids and carbon dioxide capacity.

TABLE 373

INORGANIC CONSTITUENTS OF MIXED SALIVA OF THE MOUTH CAVITY AND PLASMA  
(Babkin, 1938)<sup>1</sup>

	Milligrams/100 Cc.		
	After Clark and Snell	After Becks	After Mathis
Solids.....	733		
Organic substances.....	495		
Ash.....	225		
Chlorides.....	50	74.68	52.4
Sodium chloride.....	82		
Phosphorus.....	15.5	13.6	15.3
Calcium.....	18.9	69.88	29.7
Potassium.....	63.4	55.89	71.4
Magnesium.....	0.7	1.29	
Calcium.....	7.2	12.13	5.2
Sulfur.....	7.6		
Sulfocyanate.....	...	30.9	
$\text{CO}_2$ .....	...	93.16	
Total nitrogen.....	67.1		
Ammonia nitrogen.....	8.2		
Carbon dioxide capacity.....	...	7.153	

TABLE 374

SALIVA (NORMAL VALUES)

(Mattice, 1936)<sup>66</sup>

Volume.....	1000-1500 ml./24 hours
Specific gravity.....	1.005
Water.....	99.5 per cent
Reaction (as pH).....	6.2-7.2

*Constituents*

Inorganic salts.....	200 mg./100 ml.
Organic constituents.....	200 mg./100 ml.
Calcium (as Ca).....	4.9-7.5 mg./100 ml.
Sugar.....	None
Citric acid.....	0.04-1.3 mg./100 ml.
Nonprotein nitrogen.....	13.2 mg./100 ml.
Urea nitrogen + ammonia nitrogen.....	11.3 mg./100 ml.
Uric acid.....	1.5 mg./100 ml.

TABLE 375

MEAN VALUES FOR STIMULATED SALIVA OF CARIES-FREE AND CARIES GROUPS  
(Karshan, 1939)<sup>6</sup>

Type of Case	Num- ber of Cases	Number of Sets of Analyses	Age	Total Calcium (Mg./100 Cc.)	Inorganic Phosphorus (Mg./100 Cc.)	Per cent Calcium Removed	Per cent Phos- phorus Removed	Carbon Dioxide Capacity (Cc./100 Cc.)	Protein	
									Mg. 100 Cc.	% of Total
Caries-free.....	33	84	18.8	6.0	13.4	65	20	30.5	2.58	1.0
Arrested caries...	15	35	23.2	6.1	13.9	68	21	30.2	2.56	1.0
Active caries.....	55	146	18.9	5.2	12.1	39	45	19.5	2.84	1.0
Miscellaneous.....	45	100	21.2	5.6	13.2	48	36	23.9	3.09	1.0

TABLE 376

ANALYSIS OF MIXED SALIVAS SECRETED AT WIDELY DIFFERENT RATES  
(Adapted from Brown and Klotz, 1934)<sup>4</sup>

Group*	Volume (ML. '1 Hr.)	Chloride (Mg. '100 ML.)	PO <sub>4</sub> (Mg. '100 ML.)	Total Nitrogen (Mg. '100 ML.)	Solids (Per Cent)	Ash
Low-pro- ducing...	38.5-99	27- 52	36.6-60	41.6-75	0.39-0.60	0 10-0 1
Medium- producing	132-155.5	24- 88	34.2-64.8	25.9-57.4	0.32-0.68	0 12 0 2
High-pro- ducing...	178-310.5	42-100	24.3-45.9	31.9-66.3	0.39-0.70	0 10-0 2

\* Six subjects studied in each group.

TABLE 377

ANALYSIS OF STIMULATED AND UNSTIMULATED SALIVA\*  
(Adapted from White and Bunting, 1936)<sup>11</sup>

	Stimulated	Unstimulated
Solids (mg./100 ml.).....	342-645	243-560
Ash (mg./100 ml.).....	88-158	85-157
Calcium (mg./100 ml.).....	3.91-5.91	5.0-7.3
Phosphorus (mg./100 ml.).....	11.6-15.6	14.1-18.1
Carbon dioxide (mg./100 ml.).....	13.6-64.0	4.4-32.5

\* The subjects were twelve children, aged nine to sixteen years, all caries-free.

TABLE 378

AMINO ACID CONCENTRATION OF SALIVA  
(Adapted from Kesel et al., 1946)<sup>7</sup>

	Mg./100 ml.
Glutamic acid.....	3-12.5
Tryptophane.....	0 12-0 90
Arginine.....	3 3 10 0
Isoleucine.....	2 6-10 2
Serine.....	6-82
Valine.....	0.7-2.2

There was no apparent significant difference in the amino acid concentration of caries-free and active caries persons.

TABLE 379

VARIATIONS IN TRYPTOPHANE AND GLUTAMIC ACID CONTENT OF SALIVA DURING A 24-HOUR PERIOD

(Kesel et al., 1946)<sup>7</sup>

Samples Collected	<i>Mg. of Amino Acid per 100 ml.</i>			
	Subject A, Immune		Subject B, Caries Active	
	Glutamic Acid	Tryptophane	Glutamic Acid	Tryptophane
M.....	8.2	0.325	23.0	1.35
A.M.....	5.0	0.225	14.0	0.575
M.....	4.0	0.175	11.5	0.50
M.....	6.5	0.20	20.5	0.60

TABLE 380

MINERAL ANALYSIS OF SALIVAS SECRETED AT DIFFERENT RATES

(Adapted from Brown and Klotz, 1937)<sup>4</sup>

Group*	Volume (Ml./1 Hr.)	Sodium (Mg./100 Ml.)	Potassium (Mg./100 Ml.)	Calcium (Mg./100 Ml.)
w-producing.....	48-83	16.5-40.0	75-93	3.53-4.90
dium-producing.....	130-5-171	17.1-118.2	69.4-115.9	3.42-5.70
gh-producing.....	203-277	23.3-131.1	57.2-93	3.99-6.61

\* Six subjects studied in each group.

**HYDROGEN ION CONCENTRATION.** Brawley<sup>3</sup> found the average *pH* of normal resting saliva for 3405 cases to be 6.75; the range was 5.6 to 7.6. The average resting value is approximately midway between the values obtained by others.

The range found by various investigators<sup>5</sup> is as follows: by the electro-metric method, 4.1 to 8.6; by the colorimetric method, 5.35 to 8.0; by the indicator paper method, 5.4 to 7.2; and by unspecified methods, 3.25 to 8.0.

Brawley<sup>3</sup> determined the *pH* of normal resting saliva of males and females at different hours of the day. The *pH* was slightly higher at 7 A. M. and 12 noon. The average *pH* of all the hourly determinations (3404) for both sexes was 6.75. The average *pH* in males was 6.76; in females, 6.73. Ninety-five per cent of the 3404 determinations were in the *pH* range 6.2 to 7.4. Brawley found little difference in salivary *pH* from infancy to senescence.

**GLUCOSE.** The mean glucose concentration of saliva follows the mean blood glucose in the glucose tolerance test. There is, however, no constant blood sugar-saliva sugar ratio. The fasting saliva of children ranges from 3 to 27 mg. per 100 ml.

**PTYALIN (AMYLASE).** Meyer and Necheles<sup>9</sup> studied the basal (fasting) secretion of saliva and the secretion after a stimulus (chewing). Figure 232 illustrates

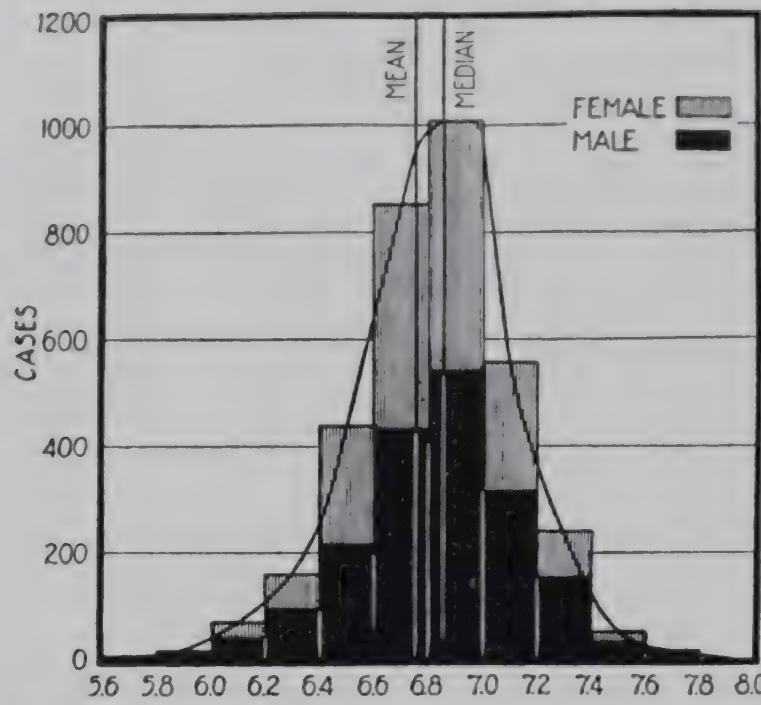


Fig. 231. Histogram and fitted curve, showing frequency distribution of pH for normal resting saliva of males and females. (R. E. Brawly, J. Dent. Res., vol. 15.)

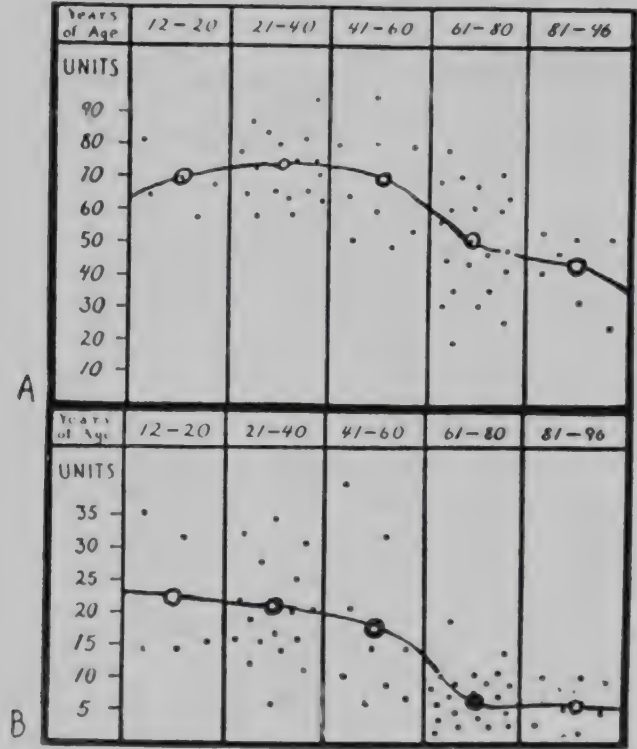


Fig. 232. Estimation of salivary ptyalin. A, Shaw and Ross method: The enzyme activity falls little in the older age groups, although a downward trend is evident. The reaction is carried to completion, i.e., to the formation of maltose. B, Wohlgemuth method: The concentration of ptyalin falls markedly about the sixtieth year of life. This reaction involves only the first step in the breakdown of starch to achroodextrin (amylolastic action,. (Meyer, J., and Necheles, H.: J.A.M.A., vol. 115.)

basal secretion of salivary amylase in thirty-two persons from twelve to twenty years of age and in twenty-nine persons from sixty to ninety years of age. The results in *A* demonstrate the formation of maltose from starch (end point method), and in *B* the formation of dextrin from starch by salivary amylase. The latter method shows the intermediary products of digestion of starch by saliva; the results obtained are important because only part of the starch ingested is digested completely (i. e., to maltose) in the mouth and stomach. The results demonstrate that the conversion of carbohydrates by salivary amylase to maltose and dextrin is markedly depressed in the aged, and particularly the formation of dextrin. Thus the first stage of starch digestion is severely depressed, while complete digestion of starch is considerably diminished. This confirms previous work in which volume and ptyalin content of stimulated salivary secretion were investigated by the Wohlgemuth method (dextrin). The values found in this work were lower than those reported before, but different groups of subjects were used, of different stock and on different nutrition.

Meyer and Nicheles suggest that there is a marked decrease or incomplete digestion of carbohydrates in the mouths and, to a certain degree, in the stomachs of old people.

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Section XIX  
MISCELLANEOUS DATA



## Chapter 70

### STATISTICAL METHODS

THE PURPOSE of this chapter is to explain in as simple terms as possible the meaning of some of the statistical methods which must be used in compiling the types of information contained in the text. This explanation will, of necessity, include a discussion of the complex field of the design of experiments, because every average, to be meaningful, implies a good experimental design.

#### PURPOSE OF STATISTICAL METHODS

The purpose of statistical methods is to derive valid generalizations from variable phenomena. Unless the data yield variable results, they may not be subjected to statistical methods. If, for example, every clinically healthy person had an oral temperature of exactly 98.6° F., it would be meaningless to call this value an average. It is because clinically healthy people do not all have the same oral temperature that an average value is desired which may be used as a norm or standard. It is probably safe to say that all physiological data are variable, and that statistical methods are therefore basic to any generalizations in physiology or medicine.

The meaning of "valid generalization" cannot be divorced from the whole field of experimental design; because in practice it implies a statistical prediction. For example, suppose the subject is the determination of the effectiveness of streptomycin treatment of patients with tuberculosis. A sample of the patients may be divided into a control group and an experimental group. The control group is given the "standard" treatment; the experimental group is given the streptomycin treatment. Now everyone knows that even if the two treatments are absolutely equally effective (what the statistician calls the null hypothesis), the experimenter is highly unlikely to obtain identical results in his two groups. Statistical methods are required to determine whether the observed results differ so much that it is unreasonable to believe that the two treatments are equally effective, or, to say the same thing, to evaluate whether it is "chance" or the difference in treatments which accounts for the variability of results. If it is believed that it is the treatments, and if the streptomycin patients fared better, any report to that effect, to be valid, implies that other tuberculous patients of this same type are expected to fare better if given the streptomycin treatment than they would under the standard treatment. The whole field of experimental design and scientific inference have therefore become a part of statistical methodology.

IMPORTANT STATISTICAL MEASURES. AVERAGES. Many averages may be computed, but the important ones to be noted here are the arithmetic mean, the median and the mode.

The *arithmetic mean* (frequently, but ambiguously, called “the average” is merely the total values of all the items divided by the number of items. It is the most important average because it is the most reliable, by which is meant that the arithmetic mean of a given size sample will usually come closer to the true arithmetic mean of a statistical “population” than the median, if

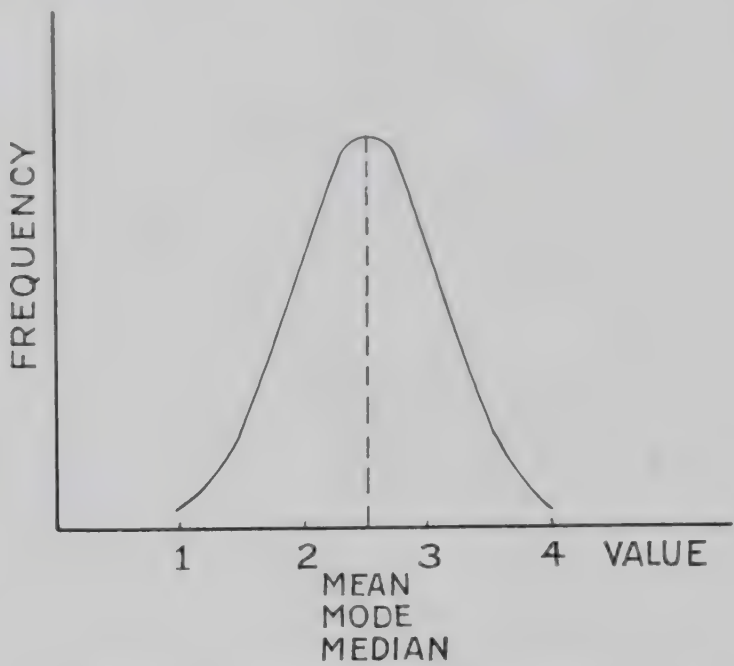


Fig. 233. A symmetrical frequency distribution.

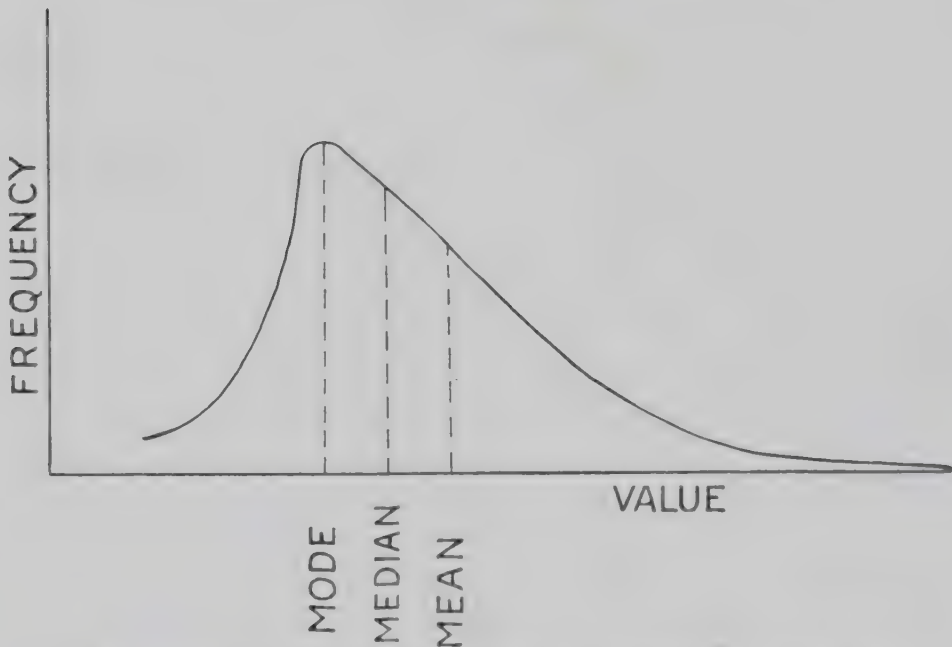


Fig. 234. A skewed frequency distribution (skewed to the right).

example, of the same sample will come to the median of the population. By “population” is meant all the values that the sample is supposed to represent.

The *median* is the middle value when all the sample values are ranked in order of magnitude. If there is an even number of observations, the median is taken to be the arithmetic mean of the two middle values. Therefore, the me

an, speaking crudely, is exceeded by half the sample values and the median exceeds half the sample values.

The *mode* is the value which occurs most frequently.

Why should there be more than one average? Restricting the discussion to frequency distributions, there would be no need for more than one average if the items always distributed themselves in a symmetrical manner. The difficulty is that phenomena are not consistently so distributed. For examples, see Figures 233 and 234.

Figure 233 is symmetrical and has one peak (unimodal). Figure 234 is skewed to the right and has one peak. In Figure 233 the mean, the median and the mode are identical and all come at the value occurring with the maximum frequency. In Figure 234 the mean is pulled farther towards the long tail than the median, and both are larger than the mode. Each of these averages has

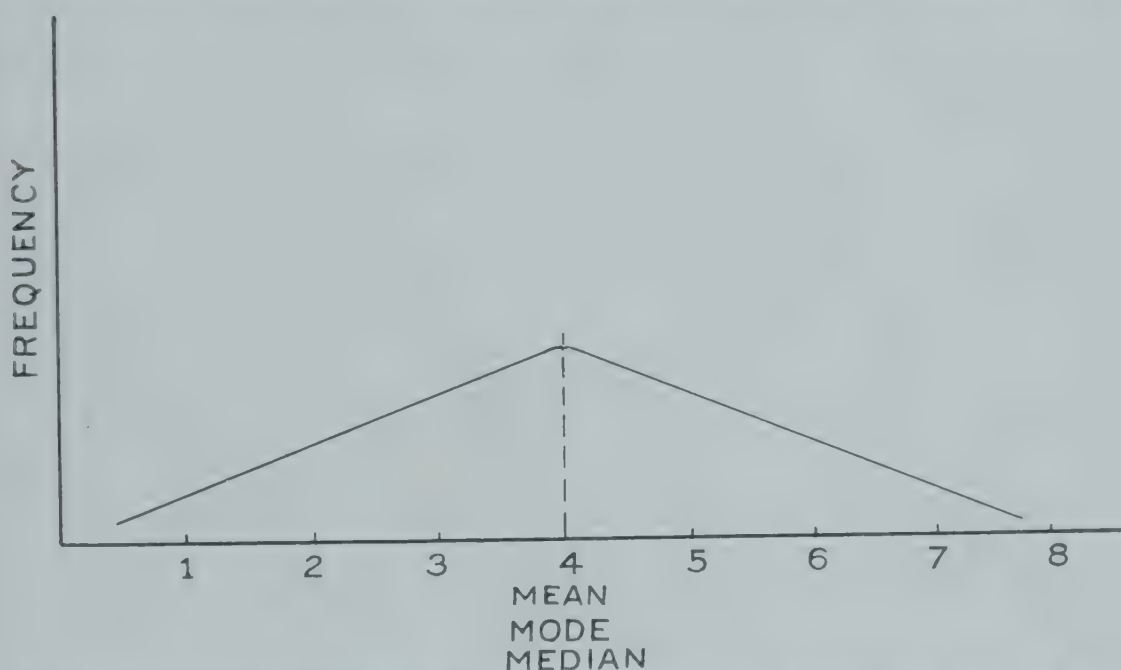


Fig. 235. A symmetrical frequency distribution with dispersion greater than that of Figure 233.

its peculiar significance. In Figure 234 the median is more representative than the arithmetic mean. In Figure 233 the mean and the median are equal and both are more "typical" than is either one in Figure 234. Therefore, from the point of view of meaningfulness, it is highly advisable, in presenting data, not only to give one or both of these two averages, but to include a picture of the frequency distribution of the observations in order that the representativeness of each average may be evaluated.

A study of Figures 233 and 235 brings out this point. Suppose that the X-scales (the horizontal scales) and the frequency scales of Figures 233 and 235 have the same distances for the same units. In both sketches the mean, the median and the mode are identical; but it is quite evident that the average value for Figure 233 is *more* representative than that for Figure 235. This information is highly pertinent, and the mere statement of an average would fail to reveal it.

It is advisable, in presenting data, to give not only the arithmetic mean but also enough information to indicate how representative it is. This may be done by giving in either tabular or graphic form the frequency distribution from which the average was derived or by including one or more measures of variability, which will be discussed in the next section. If the data are skewed it is frequently desirable to give both the arithmetic mean and the median.

**MEASURES OF VARIABILITY.** Since every average implies variability in the data, it would seem necessary to give a measure of that variability in presenting data. An average by itself is relatively meaningless. For example, suppose that the average oral temperature of clinically healthy people is determined to be 98.6° F. and is accepted as a standard. A person who appears on superficial examination to be healthy otherwise, has an oral temperature of 99.0° F. Should the physician take this as an indication that there is some obscure malady present? There is no way of telling from an average alone. A measure of the variability among clinically healthy people is required. It is only when the patient consistently falls outside the range of normality that suspicion should be aroused from temperature alone.

Again, several measures of variability are available, of which only two will be discussed here: the range and the standard deviation. The *range* is the arithmetical difference between the largest and the smallest values. For example, if in a sample of male babies at birth, the longest is 22 inches and the shortest is 18 inches, the range is 4 inches. The great advantage of the range is that it tells the extreme difference within the sample. Its main disadvantages are two: (1) It is based on the most unusual items in the sample. This difficulty may be eliminated by giving the range of the middle 96 per cent or 80 per cent or what not, in the sample; but if anything except the total range is given, the percentage included should always be specified. (2) The range is highly unreliable except that it is practically certain that the range of a sample understates the range of the population which the sample represents. How much it understates the "true" range is difficult to determine with any accuracy unless there are many experiments from samples of the same size. Nevertheless, the range is pertinent information when the size of the sample is also given, because an experienced user of the data can make intuitive adjustments which, though crude, may aid him. The reliability of the range increases with the size of sample; but as the sample size increases, the reliability of the range relative to the standard deviation decreases rapidly.

### STANDARD DEVIATION ( $\sigma$ )

The standard deviation is probably the most important statistical value. In one form or another it is the basis of evaluating the reliability of all statistical values, including itself. It is the most reliable measure of variability in the sense in which reliability has been used in this chapter. Unfortunately, the idea of the standard deviation is complex, and therefore a simple mathematical demonstration is necessary. Consider the five observations in Table 381 taken from Guilford (1942).

TABLE 381\*

COMPUTATION OF STANDARD DEVIATIONS OF SAMPLE AND POPULATION (ESTIMATED) AND OF COEFFICIENT OF VARIATION

(Guilford, 1942)

X = Strength of patellar reflex of 5 men  
under relaxed conditions (degrees  
of arc)

(2)

35

14

19

29

34

 $x = X - \bar{X}$ 

(3)

8.8

-12.2

-7.2

2.8

7.8

 $x^2$ 

(4)

77.44

148.84

51.84

7.84

60.84

 $\Sigma X = 131$  degrees $\Sigma x = 0.0$  $\Sigma x^2 = 346.80$  $\bar{X} = \frac{\Sigma X}{N} = \frac{131}{5} = 26.2$  degrees = Arithmetic mean of sample. $\sigma^2 = \frac{\Sigma x^2}{N} = \frac{346.80}{5} = 69.36$  = Variance of sample. $\sigma' = \sqrt{\sigma^2} = \sqrt{69.36} = 8.3$  degrees = Standard deviation of sample. $\sigma_P = \sigma \sqrt{\frac{N}{N-1}} = 8.3 \sqrt{\frac{5}{4}} = 8.3 \times 1.118 = 9.3$  degrees = Estimated standard deviation of population. $V = \frac{\text{est } \sigma_P}{\bar{X}} \times 100 = \frac{9.3}{26.2} \times 100 = 35$  per cent = Coefficient of variation.

\* By permission from Fundamental Statistics in Psychology and Education, by J. P. Guilford, Copyrighted, 1942. McGraw-Hill Book Co., Inc.

The procedure for getting the standard deviation of the sample is as follows (short-cut methods and methods applicable for data grouped into a frequency distribution may be found in appropriate texts):

1. Let  $X$  be the original variable being observed (degrees of arc in this case).
2. Let  $N$  be the number of observations in the sample.
3. Compute the arithmetic mean:  $\bar{X} = \frac{\Sigma X}{N}$ .
4. Obtain the deviation of each observed value from the arithmetic mean:  $x = X - \bar{X}$ . Notice that  $\Sigma x = 0$  unless values have been rounded.
5. Square each such deviation and add:  $\Sigma x^2$ . This is called the sum of the squared deviations from the arithmetic mean.
6. Get the arithmetic mean of the squared deviations:  $\sigma^2 = \frac{\Sigma x^2}{N}$ . This  $\sigma^2$  is called the sample variance around the mean.
7. The standard deviation of the sample,  $\sigma$ , is the square root of the variance:  $\sigma = \sqrt{\sigma^2}$ , always taken as positive.

It is apparent that this standard deviation is a measure of variation, because it can be zero only if every  $X$  equals the mean, which means that there is no variability. The bigger the squared deviations,  $N$  remaining constant, the bigger the standard deviation. This measure, however, like the range, has one major defect: The standard deviation of the sample tends to be less than the standard deviation of the population in which the experimenter is interested. The smaller the sample, the greater the average understatement. An adjustment, however, yields a good estimate of the standard deviation of the population, especially if the size of the sample is reasonably large. This adjustment is as follows:

8.  $\text{Est } \sigma_P = \sigma \sqrt{\frac{N}{N-1}}$ , estimated standard deviation of the population. Another defect of the standard deviation is that the comparison of the variability of characteristics expressed in different units (inches vs. pounds) is impossible. This defect is corrected by computing the coefficient of variation:

9. Coefficient of variation =  $\frac{\text{est } \sigma_P}{X} \times 100$  (in percentage form). This coefficient may now be compared with another similar coefficient to answer the question: Are human beings more variable in this characteristic than in that one?

There are two other uses of the standard deviation, aside from evaluating sample reliability (to be discussed later) which may be mentioned here.

1. If the items are distributed in accordance with the normal curve, probability statements may be made from an examination of Table 382. These probabilities apply only to the normal curve, a bell-shaped curve with certain specific properties, appearing somewhat like Figure 233.

TABLE 382

PROBABILITY OF AN ITEM DEVIATING AS MUCH FROM THE MEAN AS THE ONE OBSERVED WHEN THE UNDERLYING DISTRIBUTION IS NORMAL

<i>Number of Standard Deviations the Given Item Is away from Mean</i>	<i>Probability of Being as Far away from the Mean or Farther in Either Direction</i>		<i>in Given Direction</i>
0.67449	0.5000		0.2500
1.0	0.3174		0.1587
1.96	0.0500		0.0250
2.0	0.0454		0.0227
2.575	0.0100		0.0050
3.0	0.0027		0.00135

For example, if the underlying distribution is normal, 5 per cent of the items will be 1.96 or more standard deviations away from the mean, of which half, or 2½ per cent of the total, will be above the mean.

2. If the data are not badly skewed, and if the sample is not large (say, less than 50), suspicion is cast on any item falling more than three standard deviations (est  $\sigma_P$ ) away from the mean. One of the most difficult decisions to be made is to know when to discard items from the computations. This is a mechanical aid. Any such item should be reexamined with care before the decision is made to include or exclude it. The main question to ask in making the decision is this: Is this item really homogeneous with the others? Homogeneity will be defined subsequently in this chapter.

STANDARD ERROR AND PROBABLE ERROR

In Table 381 the emphasis was on the study of individual items and the generalizations to be made from them. The two main measures emphasized were the arithmetic mean and the standard deviation, because it was stated that these were the most reliable values of averages and measures of variation, respectively. It is still true, however, that these values are not completely

able, and one wants a measure of their reliability. The important measure of reliability for any statistical value such as the mean, median, range, standard deviation or coefficient of correlation, is its standard error. To illustrate the meaning of this concept the standard error of the mean only will be discussed. At least, two general definitions are required:

1. The *standard error* of any statistical value, such as the mean, is the standard deviation of the random sampling distribution of that statistical value for samples of the given size.
2. The *probable error* of any statistical value, such as the mean, is equal to 0.67449 . . . times the standard error of that same value. The concept of the probable error is becoming less and less important in statistical literature. There is no need for it, and its limitations will be outlined later.

The meaning of "standard error" is difficult to grasp. Assume that the investigator is interested in determining "standard" oral temperature of clinically healthy people. Assume further that this value is independent of the latitude and longitude of the residence of the person and also of time; that is, the value is presumed to be the same in 1900, 1948 or 1968. All clinically healthy people living anywhere or at any time, past, present, or future, comprise the statistical population. There is an indefinitely large number of such people in the population. If all such people could be examined, their temperatures could be classified in the form of a frequency distribution and plotted with results appearing, presumably, something like either Figure 233 or 234. The arithmetic mean could be computed for all these values, and if it were a representative value because the distribution was not badly skewed, it would probably be accepted as the standard. This value is the one the experimenter wishes to estimate. How does he do it? The method is as follows:

1. A random sample of individuals is selected. By random is meant ideally that every clinically healthy person has an equal opportunity with all others of getting into the sample. Since this condition is impossible to fulfill, practically, the assumption must be made that the statistics of the sample actually selected will not differ from those of one that would have been selected in the ideal manner.

2. The mean of the sample is computed.

3. It is recognized that it is highly unlikely that this sample mean will equal the population mean. Therefore an estimate must be made of the probability that the sample mean would depart by chance more than any given distance (degrees) from the true value. To make this estimate, which is based on the standard error, one must know the random sampling distribution of means for samples of the given size. Fortunately, that distribution is adequately known, and may be pictured as in Figure 236, which shows what would have happened if, instead of taking only one sample, the investigator had taken an indefinitely large number of random samples *all of the same size*. The means of these samples would have been symmetrically distributed (this is not true for any statistical values, including the standard deviation and the coefficient of correlation), with more sample means falling at the mean of the population than at any other point.

Now the single sample actually taken yielded one of the sample means pictured in Figure 236. Which one? Of course nobody knows; but if one could estimate the standard deviation of the distribution of means, he could say that it was highly unlikely that his sample mean was more than two or three of these standard deviations away from the true population mean. This standard deviation is called the standard error of the mean. For each statistical value

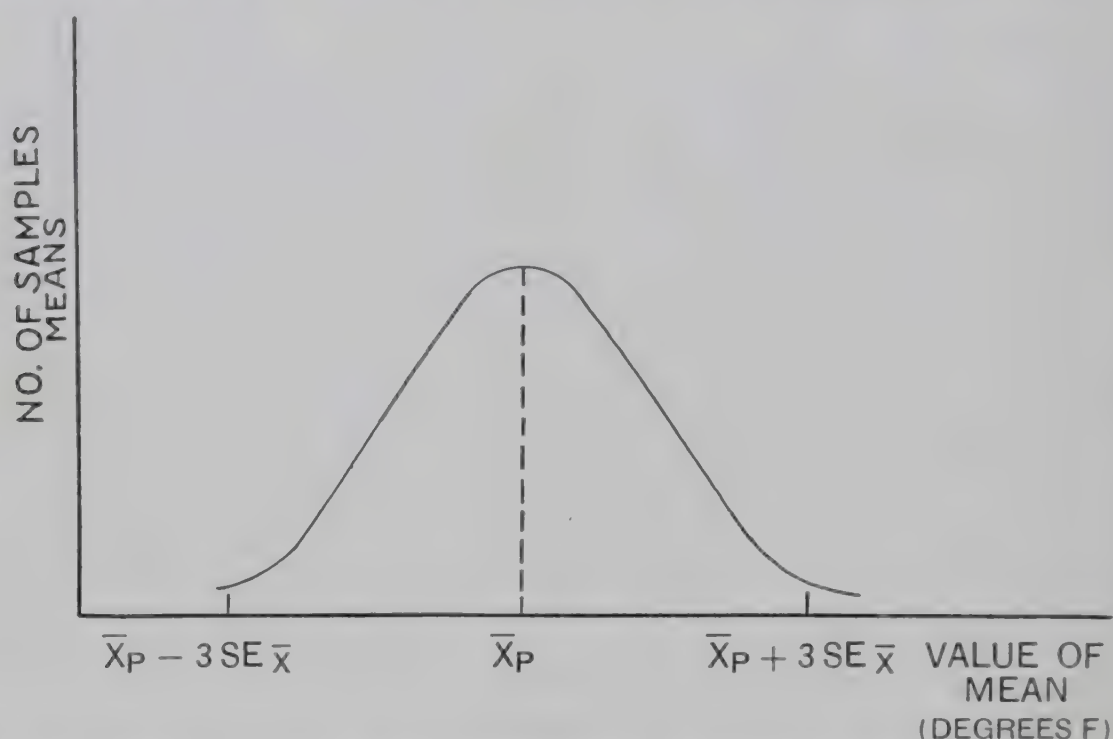


Fig. 236. Random sampling distribution of means of samples of size  $N$  taken from a given population.

such as the mean, standard deviation or coefficient of correlation, there is a formula available for estimating the comparable standard error. For the arithmetic mean, it is as follows:

$$\text{Est. S.E.}\bar{X} = \frac{\text{est. } \sigma_P}{\sqrt{N}},$$

where  $\text{est. S.E.}\bar{X}$  means estimated standard error of the mean.

Now let us apply this formula to the data of Table 381, assuming that the sample to be taken under random conditions, and then interpret the results.

1. The mean of the sample,  $\bar{X} = 26.2$  degrees of arc.
2. The estimated standard deviation of the population,  $\text{est. } \sigma_P = 9.3$  degrees of arc.
3. From this, the estimated standard error of the mean is obtained as follows, where  $N$  is the size of sample, or 5 in this case:

$$\text{est S.E.}\bar{X} = \frac{\text{est. } \sigma_P}{\sqrt{N}} = \frac{9.3}{\sqrt{5}} = \frac{9.3}{2.236} = 4.2 \text{ degrees of arc.}$$

4. It is unlikely (probability of 0.05 to 0.1) that the mean we obtained (26.2) is farther than two standard errors from the true mean of the population. Therefore it is unlikely that the true mean will fall outside the limits  $\bar{X} \pm 2 \text{ S.E.}\bar{X}$ , or  $26.2 \text{ degrees} \pm 2 \times 4.2 \text{ degrees}$ , or  $26.2 \text{ degrees} \pm 8.4 \text{ degrees}$ . This means that we think that the true value is quite likely (probability of 0.9 to 0.95) of falling within the limits of 17.8 and 34.6 degrees. (Note: Since some other

statistical values such as the standard deviation and the coefficient of correlation frequently do not yield symmetrical random sampling distributions, the form of presentation should practically never be  $\pm$ . For example, one should practically *never* write a coefficient of correlation in the form:  $0.9 \pm 0.04$ , even though this mistake is commonly made. It would probably be  $0.9$  with limits for given probability of  $0.84$  to  $0.93$ .

Notice that only an approximate probability has been stated. The chief limitation of the probable error—a psychological limitation—may now be illustrated. It is customary in the literature to proceed as follows:

1. Compute the probable error of the mean. In the example this would be:  $P.E.\bar{x} = 0.67449 \times 4.2 \text{ degrees} = 2.8 \text{ degrees}$ .
2. State the conclusion as  $\bar{X} \pm P.E.\bar{x} = 26.2 \text{ degrees} \pm 2.8 \text{ degrees}$ .

What is the meaning of this statement? Too many people think that it means that the true mean is within the stated limits. This is not likely to be true. Under perfect experimental conditions and if all assumptions are met absolutely, it means that the probability is one-half that the true value does *not* fall within these limits. It is highly unlikely that the experiment was set up perfectly and even more unlikely that all other assumptions required will hold good. Therefore, it is highly unlikely that the probability is one-half, as is usually implied. It is much better practice to establish limits of the mean plus or minus two or even three standard errors and to use approximate probability statements, as just exemplified. For three standard errors, the probability for a well-designed experiment should be of the order of  $0.95$  to  $0.99$  that the true mean will fall within the stated limits, especially if the sample size is relatively large.

Three final observations may be made on the standard error:

1. The less the variability in the population, the less the standard error for a given size sample. Therefore, the greater the "precision of estimate."
2. The larger the sample taken from a given population, the smaller the standard error.
3. Standard error, in any event, is a meaningless concept unless it may be presumed that the sample has been taken at random from the specified population.

## REQUIREMENTS OF A GOOD SET OF STATISTICAL DATA

1. The data should be homogeneous. Homogeneous data are those requiring further subclassification. It is relatively meaningless, for example, to study from an anatomical viewpoint the heights of human beings, because there is a large difference between the heights of men and of women, of adult men and of children aged five years, and so forth. As another example, persons are not homogeneous in their response to x-ray treatments, and it is necessary to establish different exposure for people of various types, or grave difficulties may be encountered in particular cases.

A special case where homogeneity must be emphasized is in the experimental design required to determine whether one therapy is better than another. Unless the patients in the control and experimental groups are homogeneous except for therapy, the question posed cannot be answered. If more patients

who would recover anyway are in one group and more who would die anyway are in the other, the experiment cannot show anything about the relative merits of the therapies.

II. There should be no changing systematic error throughout the experiment. Systematic error concerns the effectiveness of experimental controls. It is frequently the case that as one proceeds with the experiment, the systematic error is changed because one learns how to conduct the experiment better. Under these conditions it is highly inadvisable to publish the entire set of results in one table. A good set of data implies constant controls. There are statistical techniques available to test for such constancy.

III. The data should be presented in such a way that all pertinent statistical information is available. This usually implies that there should at least be given the size of sample and sufficient information about the distribution of items to evaluate the representativeness of the average and the reliability of the required statistical measures. If one is interested primarily in averages, it is probably advisable to give as a minimum, for example, the size of sample, the mean, the median and the standard deviation. Wherever possible it is even more helpful to include the entire frequency distribution of results in order that interested readers may analyze them. It will be noted that few tables given in the body of this text fulfill this requirement.

IV. Where two groups are being studied for some characteristic, statement should be made concerning the significance of the difference between the two results. A significant difference means that one believes that two different populations, not one, are being studied. An insignificant difference means that the statistical value for the two populations can be considered identical. For example, if it is said that there is a significant difference between the weights of males and females at birth, it implies that the mean weights in the statistical populations of males and females differ. If there is an insignificant difference claimed, on the basis of a sample, between the IQ's of men and women, it implies that the mean IQ of all men may be considered identical with the mean IQ of all women. Techniques are available in statistical texts for evaluating the significance of differences, assuming that the experiment is well designed.

## BIBLIOGRAPHY

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## Chapter 71

### FOOD VALUES

TWO METHODS of estimating the nutritive value of a diet\* are suggested in the following tables. One is the usual procedure in which separate computations of individual values for each item of food are given; the other is a short method by which foods of similar composition are grouped together and the mean values for each of the nutrients are used.

When computing individual values for each food, refer to Tables 384 and 385.† Tables 386, 387, 388, 389, 390, 391 and 392 are included as an aid in estimating other constituents in the dietary.

The short method (see Table 393, p. 758) may be sufficiently accurate for estimating the adequacy of a varied diet. It is time-saving without sacrificing accuracy in view of the wide variation in the composition of any given food.

TABLE 383  
RECOMMENDED DAILY DIETARY ALLOWANCES\*  
REVISED 1948

(National Research Council, Reprint and Circular Series No. 129)

	Calories (1)	Protein (Grams)	Calcium (Grams)	Iron (Mg.)	Vitamin A <sup>(2)</sup> (I. U.)	Thia- mine (3) (Mg.)	Ribo- flavin (3) (Mg.)	Niacin (Nico- tinic acid) (3) (Mg.)	Ascor- bic Acid (Mg.)	Vitami D (I.U.)
Man (154 lb., 70 kg.)										
Sedentary.....	2400	70	1.0	12(4)	5000	1.2	1.8	12	75	(5)
Physically active...	3000	70	1.0	12(4)	5000	1.5	1.8	15	75	(5)
With heavy work...	4500	70	1.0	12(4)	5000	1.8	1.8	18	75	(5)
Woman (123 lb., 56 kg.)										
Sedentary.....	2000	60	1.0	12	5000	1.0	1.5	10	70	(5)
Moderately active..	2400	60	1.0	12	5000	1.2	1.5	12	70	(5)
Very active.....	3000	60	1.0	12	5000	1.5	1.5	15	70	(5)
Pregnancy (latter half).....	2400(6)	85	1.5	15	6000	1.5	2.5	15	100	400
Lactation.....	3000	100	2.0	15	8000	1.5	3.0	15	150	400
Children up to 12 yrs.(7)										
Under 1 yr.(8).....	110/2.2 lb. (1 kg.)	3.5/2.2 lb. (1 kg.)	1.0	6	1500	0.4	0.6	4	30	400
1-3 yrs. (27 lb., 12 kg.).....	1200	40	1.0	7	2000	0.6	0.9	6	35	400
4-6 yrs. (42 lb., 19 kg.).....	1600	50	1.0	8	2500	0.8	1.2	8	50	400
7-9 yrs. (58 lb., 26 kg.).....	2000	60	1.0	10	3500	1.0	1.5	10	60	400
10-12 yrs. (78 lb., 35 kg.).....	2500	70	1.2	12	4500	1.2	1.8	12	75	400
Children over 12 yrs.(7)										
Girls, 13-15 yrs. (108 lb., 49 kg.)..	2600	80	1.3	15	5000	1.3	2.0	13	80	400
Girls, 16-20 yrs. (122 lb., 55 kg.)..	2400	75	1.0	15	5000	1.2	1.8	12	80	400
Boys, 13-15 yrs. (108 lb., 49 kg.)..	3200	85	1.4	15	5000	1.5	2.0	15	90	400
Boys, 16-20 yrs. (141 lb., 64 kg.)..	3800	100	1.4	15	6000	1.7	2.5	17	100	400

\* See Table 383 for dietary allowances recommended by the Food and Nutrition Board, National Research Council.

† For additional food items, refer to Bowes and Church<sup>1</sup> and Bridges and Mattice.<sup>2</sup>

Objectives toward which to aim in planning practical dietaries: The recommended allowances can be attained by a good variety of common foods which will also provide other minerals and vitamins for which requirements are well known.

Calorie allowances must be adjusted up or down to meet specific needs. The calorie values in the table are not applicable to all persons, but rather represent group averages. The proper calorie allowances are those which will extend a period will maintain body weight or rate of growth at the level most conducive to well-being.

The allowance depends on the relative amounts of vitamin A and carotene. The allowances of the table are based on the premise that approximately two-thirds of the vitamin A value of the average diet in this country is contributed by carotene and that carotene has half or less than half the value of vitamin A.

For adults (except pregnant and lactating women) receiving diets supplying 2000 calories or less, such as in the table, the allowances of thiamine and niacin may be 1 mg. and 16 mg., respectively. The fact that figures are given for different calorie levels for thiamine and niacin does not imply that we can estimate the requirement of these vitamins on the basis of calorie level; they are added merely for simplicity of calculation. In the present revision, riboflavin allowances are based on body weight rather than calorie levels. Other members of the B complex also are required, though they are not given. Foods supplying adequate thiamine, riboflavin and niacin will tend to supply sufficient of the other B vitamins.

There is evidence that the male adult needs relatively little iron. The need will usually be provided for in the diet and is satisfactory in other respects.

The need for supplemental vitamin D by vigorous adults leading a normal life seems to be minimum. For persons working at night and for nuns and others whose habits shield them from the sunlight, as well as for elderly persons, the ingestion of small amounts of vitamin D is desirable.

During the latter part of pregnancy the calorie allowance should increase approximately 20 per cent above the level. The value of 2400 calories represents the allowance for pregnant, sedentary women.

Allowances for children are based on the needs for the middle year in each group (as 2, 5, 8, and so on) and on moderate activity and for average weight at the middle year of the age group.

Needs for infants increase from month to month with size and activity. The amounts given are for approximately 6 to 8 months. The dietary requirements for some of the nutrients such as protein and calcium are less if derived from human milk.

Little information is available concerning the human requirement for fat. Fat allowances must be based on the nature of food habits and on physiologic requirements. While a requirement for certain unsaturated fatty acids (the linoleic and arachidonic acids of natural fats) has been amply demonstrated with experimental animals, the need for these fatty acids is not known. In spite of the paucity of information on this subject, several factors make it desirable (1) that fat be included in the diet to the extent of at least 20 to 25 per cent of the total calories and (2) that the fat intake include essential unsaturated fatty acids to the extent of at least 1 per cent of the total calories. On the basis of calorie expenditure—e.g., for a very active person consuming 4500 calories and for children and for sedentary persons—it is desirable that 30 to 35 per cent of the total calories be derived from fat. Since foodstuffs such as meat, milk, cheese, nuts, and so forth, contribute fat to the diet, it is necessary to use separated or "y-scale" fats as butter, oleomargarine, lard or shortenings to supply only one-third to one-half the amounts indicated.

Water. A suitable allowance of water for adults is 2.5 liters daily in most instances. An ordinary standard for diverse persons is 1 milliliter for each calorie of food. Most of this quantity is contained in prepared foods. At work or in hot weather, requirements may reach 5 to 13 liters daily. Water should be allowed *ad libitum*, since sensations of thirst usually serve as adequate guides to intake except for infants and sick persons.

Salt. The needs for salt and for water are closely interrelated. A liberal allowance of sodium chloride for the adult is 10 to 15 gm. daily, except for some persons who sweat profusely. The average normal intake of salt is 10 to 15 gm. daily, amount which meets the salt requirements for a water intake up to 4 liters daily. When sweating is excessive, one additional gram of salt should be consumed for each liter of water in excess of 4 liters daily. With heavy work or in hot climates 20 to 30 gm. daily may be consumed with meals and in drinking water. Even then, most persons do not consume more salt than usually occurs in prepared foods. It has been shown that after acclimatization, persons produce sweat that contains only about 0.5 gm. to the liter in contrast with a content of 2 to 3 gm. for sweat of the unacclimated person. Consequently, after acclimatization, need for increase of salt beyond that of ordinary food disappears.

Iodine. The requirement for iodine is small, probably about 0.002 to 0.004 mg. daily for each kilogram of body weight, or a total of 0.15 to 0.30 mg. daily for the adult. This need is met by the regular use of iodized salt; its use is especially important in adolescence and pregnancy.

Phosphorus. Available evidence indicates that the phosphorus allowances should be at least equal to those for calcium in the diets of children and of women during the latter part of pregnancy and during lactation. For other adults the phosphorus allowances should be approximately 1.5 times those for calcium. In general it is safe to assume that if calcium and protein needs are met through common foods, the phosphorus requirement also will be covered, because common foods richest in calcium and protein are also the best sources of phosphorus.

Copper. The requirement for copper for adults is about 1 to 2 mg. daily. Infants and children require approximately 1 mg. for each kilogram of body weight. The requirement for copper is approximately one-tenth that for iron. A diet normally will supply sufficient copper.

Vitamin K. The requirement for vitamin K usually is satisfied by any good diet except for the infant in utero and for the first few days after birth. Supplemental vitamin K is recommended during the last month of pregnancy. When not given in this manner, it is recommended for the mother before delivery or for the baby immediately after birth.

Folic Acid. The quantitative requirement of folic acid (pteroylglutamic acid, vitamin B<sub>12</sub>, *L. casei* factor or vitamin B<sub>9</sub>) as an essential human nutrient cannot be closely estimated from evidence now available.

TABLE 384

## NUTRITIVE VALUES OF SELECTED FOODS, EDIBLE PORTION\*

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
MILK, CREAM, ICE CREAM, CHEESE															
Milk:															
1. Buttermilk, cultured	240.00	8 oz., 1 cup	90.5	3.5 8.4	0.1 0.24	5.1 12.2	35 84	118.0 283.0	93 223	0.07 0.168	trace	0.04 0.096	0.18 0.432	0.1 0.24	1.0 2.0
2. Chocolate flavored	180.00	$\frac{1}{2}$ c., 5 oz. milk	83.0	3.2 5.8	2.2 3.9	10.6 19.1	75 136	109.0 196.0	91 165	0.07 0.13	90 162	0.03 0.054	0.16 0.288	0.1 0.18	0 ?
3. Condensed, sweetened	15.00	1 tbsp.	27.0	8.1 1.2	8.4 1.3	54.8 8.2	327 49	273.0 41.0	228 34	0.20 0.03	430 65	0.05 0.008	0.39 0.058	0.2 0.03	1
4. Dry skim	28.35	1 oz.	3.5	35.6 10.1	1.0 0.3	52.0 14.7	359 102	1300.0 368.0	1030 292	0.58 0.16	40 11	0.35 0.099	1.96 0.555	1.1 0.3	7.0 1.9
5. Dry whole	28.35	1 oz.	3.5	25.8 7.3	26.7 7.6	38.0 10.8	496 141	949.0 271.0	728 206	0.58 0.16	1400 400	0.30 0.085	1.46 0.413	0.7 0.19	6.0 1.7
6. Evaporated, unsweet- ened	126.00	$\frac{1}{2}$ c.	73.7	7.0 8.8	7.9 10.0	9.9 12.4	139 175	243.0 306.0	195 245	0.17 0.21	400 504	0.05 0.063	0.36 0.453	0.2 0.25	1.0 1.2
7. Fresh skim	240.00	8 oz., 1 c.	90.5	3.5 8.4	0.1 0.2	5.1 12.2	35 84	118.0 283.0	93 223	0.07 0.168	trace	0.04 0.096	0.18 0.432	0.1 0.24	1.0 2.4

\* Figures in bold face represent the nutritive value of 100 gm., edible portion. The other figures represent the nutritive values of household measures commonly used. The values for 100 gm. portions are those expressed in Misc. Pub. No. 572, U.S. Department of Agriculture, prepared by the Bureau of Human Nutrition and Home Economics in cooperation with the National Research Council.

8. Fresh whole	240.00	8 oz., 1 c.	87.0	3.5	3.9	4.9	69	118.0	93	0.07	160	0.04	0.17	0.1	1.0
				8.2	9.4	11.8	165	283.0	223	0.168	384	0.096	0.408	0.24	2.4
Cream, Ice Cream:															
9. Cream (20%) sweet or sour	28.35	1 oz., 2 tbsp.	72.5	2.9	20.0	4.0	208	97.0	77	0.06	830	0.03	0.14	0.1	1.0
				0.8	5.7	1.1	59	27.4	21	0.017	235	0.009	0.039	0.028	
10. Ice cream, plain	71.00	$\frac{1}{8}$ of 1 qt. commercial	62.0	4.0	12.3	20.8	210	132.0	104	0.10	540	0.04	0.19	0.1	trace
				2.9	8.8	14.8	150	94.0	74	0.07	383	0.028	0.135		
Cheese:															
11. Cheddar	28.35	1 oz., av. serv.	39.0	23.9	32.3	1.7	393	873.0	610	0.57	1740	0.04	0.50	0.2	0
				6.8	9.2	0.5	112	247.0	174	0.161	493	0.011	0.155	0.06	0
12. Cottage cheese	30.00	1 rounded tbsp.	74.0	19.2	0.8	4.3	101	82.0	263	0.45	30	0.02	0.29	0.1	0
				5.8	0.24	1.3	30	25.0	79	0.138	9	0.006	0.087	0.039	0
13. Cream cheese	28.35	1 oz.	53.3	7.1	36.9	1.7	367	298.0	238	0.17	2210	0.01	0.14	0.1	0
				2.0	10.5	0.5	104	85.0	59	0.048	626	0.002	0.04	0.02	0
14. Processed, canned cheddar	28.35	1 oz.	37.5	21.9	31.8	2.0	382	716.0	831	0.76	1260	0.03	0.43	0.1	0
				6.2	9.0	0.5	108	203.0	237	0.22	360	0.008	0.12	0.02	0
15. All other	28.35	1 oz.	39.0	23.9	32.3	1.7	393	873.0	610	0.57	2050	0.04	0.52	0.2	0
				6.8	9.2	0.5	112	247.0	174	0.161	581	0.011	0.155	0.06	0
FATS															
16. Bacon, medium fat	15.00	3 strips 4"x1"	20.0	9.1	65.0	1.1	626	13.0	108	0.8	0	0.42	0.10	2.1	0
				1.4	9.8	0	94	2.0	16	0.12	0	0.063	0.015	0.315	0

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A I.U.	Thia- mine (Mg.)	Ribofl- avin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
17. Butter	13.00	1 tbsp.	15.5	0.6 0.08	81.0 10.5	0.4 0.052	733 95	16.0 2.0	16 2	0.2 0.03	3300 429	trace 0	0.01 trace	0.1 trace	0 0
18. French dressing	11.00	1 tbsp.	38.3	0.8 0	39.0 4.2	17.3 1.9	423 46	5.0 0	5 0	0.1 0	0 0	0 0	0 0	0 0	0 0
19. Lard, other shortening	11.00	1 tbsp.	0	0 0	100.0 11.0	0 0	900 99	0 0	0 0	0 0	0 1	0 0	0 0	0 0	0 0
20. Margarine with vita- min A added	13.00	1 tbsp.	15.5	0.6 0.08	81.0 10.5	0.4 0.05	733 95	2 0	15 0	0.2 0	1980 257	0 0	0 0	0 0	0 0
21. Mayonnaise	14.00	1 tbsp. (1 egg used)	16.0	1.5 0.2	78.0 10.9	3.0 0.5	720 100	19.0 3.0	60 8	1.0 0.1	210 29	0.04 0	0.04 0	0 0	0 0
22. Salad or cooking oil	11.00	1 tbsp.	0	0 0	100.0 11.0	0 0	900 99	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
23. Salt pork, fat	100.00	1 sl. 5x2x1"	8.0	3.9 3.9	85.0 85.0	0 0	781 781	2.0 2.0	42 42	0.6 0.6	0 0	0.18 0.18	0.04 0.04	0.9 0.9	0 0
Eggs 24. Egg yolk, fresh	16.00	1 average	49.4	16.3 2.6	31.9 5.1	0.7 0.1	355 57	147.0 24.0	586 94	7.2 1.1	3210 519	0.32 0.05	0.52 0.09	0 0	0 0

	28.35	1 oz.	13.8	12.3	0.73	168	53.0	227	2.5	1266	0.09	0.35	—	0
26. Eggs, whole, fresh	50.00	1 med., average	74.0	12.8 6.4	11.5 5.8	0.7 0.4	158 79	54.0 27.0	210 105	2.7 1.4	0.12 0.06	0.34 0.17	0.1 0.05	0 0
MEATS, POULTRY, FISH														
Beef:														
27. Chuck roast	100.00	3½ oz.	65.0	18.6 18.6	16.0 16.0	0 0	218 218	11.0 11.0	200 200	2.8 2.8	0.12 0.12	0.15 0.15	5.0 5.0	0 0
28. Corned beef, canned	30.00	1 oz., 1 slice	57.3	24.4 7.3	15.0 4.5	0 0	232 70	29.0 9.0	113 34	4.0 1.2	0.02 0.06	0.19 0.057	2.7 0.08	0 0
29. Corned beef, dried or chipped	30.00	1 oz., 2 sl.	47.7	34.3 10.3	6.3 1.9	0 0	194 58	20.0 6.0	370 111	5.1 1.5	0.11 0.033	0.22 0.066	3.7 1.11	0 0
30. Corned beef, medium	30.00	1 oz.	54.2	15.8 4.7	25.0 7.3	0 0	288 87	9.0 3.0	170 51	2.4 0.7	0.05 0.015	0.10 0.03	1.7 0.5	0 0
31. Hamburger	85.00	1 (5 from 1 lb.)	55.0	16.0 13.6	28.0 23.0	0 0	316 267	9.0 7.0	172 146	2.4 2.0	0.10 0.08	0.13 0.11	4.3 3.6	0 0
32. Loaf steaks	100.00	1 steak, sm.	57.0	16.9 16.9	25.0 25.0	0 0	293 293	10.0 10.0	182 182	2.5 2.5	0.10 0.10	0.13 0.13	4.6 4.6	0 0
33. Roasting meat (average)	100.00	3½ oz.	67.0	18.9 18.9	13.0 13.0	0 0	193 193	11.0 11.0	204 204	2.8 2.8	0.12 0.12	0.15 0.15	5.1 5.1	0 0
34. Rib roast or steak	100.00	3½ oz.	59.0	17.4 17.4	23.0 23.0	0 0	277 277	10.0 10.0	188 188	2.6 2.6	0.11 0.11	0.14 0.14	4.7 4.7	0 0
35. Round steaks	100.00	3½ oz.	67.0	19.3 19.3	13.0 13.0	0 0	194 194	11.0 11.0	208 208	2.9 2.9	0.12 0.12	0.15 0.15	5.2 5.2	0 0

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
36. Roast, rump	100.00	3½ oz.	53.0	15.5 15.5	31.0 31.0	0 0	341 341	9.0 9.0	167 167	2.3 2.3	0 0	0.10 0.10	0.12 0.12	4.2 4.2	0 0
37. Stew meat (73% lean)	100.00	3½ oz.	53.0	15.8 15.8	30.0 30.0	0 0	333 333	9.0 9.0	170 170	2.4 2.4	0 0	0.10 0.10	0.12 0.12	4.3 4.3	0 0
Lamb:															
38. Lamb chop, sirloin	50.00	1 med.	63.7	18.0 9.0	17.5 8.7	0 0	230 115	10.0 5.0	194 97	2.7 1.4	0 0	0.21 0.105	0.26 0.13	5.9 2.9	0 0
39. Leg or shoulder roast	70.00	1 serv.	63.7	18.0 12.6	17.5 12.3	0 0	230 161	10.0 7.0	194 136	2.7 1.9	0 0	0.21 0.148	0.26 0.182	5.9 4.2	0 0
Pork:															
40. Miscellaneous, lean cuts	100.00	3½ oz.	52.0	14.5 14.5	32.7 32.7	0 0	352 352	8.0 8.0	156 156	2.2 2.2	0 0	0.92 0.92	0.18 0.18	3.9 3.9	0 0
41. Ham, fresh	100.00	3½ oz.	53.0 53.0	15.2 15.2	31.0 31.0	0 0	340 340	9.0 9.0	164 164	2.3 2.3	0 0	0.96 0.96	0.19 0.19	4.1 4.1	0 0
42. Ham, picnic	100.00	3½ oz.	52.0	14.8 14.8	32.0 32.0	0 0	347 347	9.0 9.0	160 160	2.2 2.2	0 0	0.94 0.94	0.18 0.18	4.0 4.0	0 0
43. Ham, smoked	100.00	3½ oz.	42.0	16.9 16.9	35.0 35.0	0.3 0.3	384 384	10.0 10.0	182 182	2.5 2.5	0 0	0.78 0.78	0.19 0.19	3.8 3.8	0 0

44. Pork chop, loin	70.00	1 chop	58.0	16.4	23.0	0	291	10.0	177	2.9	0	0	0.728	0.140	3.08	0
				11.5	17.5	0	204	7.0	124	1.7						0
45. Pork links sausage	58.00	3 links, 3" long	41.9	10.8	44.8	0	446	6.0	116	1.6	0	0	0.22	0.15	2.3	0
				6.3	25.9	0	259	4.0	67	0.93	0	0	0.15	0.105	1.6	0
Veal:																
46. Leg roast, or steak	100.00	3½ oz.	68.0	19.1	12.2	0	186	11.0	206	2.9	0	0	0.17	0.27	6.3	0
				19.1	12.2	0	186	11.0	206	2.9	0	0	0.17	0.27	6.3	0
47. Stew meat, 74% lean	100.00	3½ oz.	64.0	18.3	17.0	0	226	11.0	197	2.7	0	0	0.17	0.26	6.0	0
				18.3	17.0	0	226	11.0	197	2.7	0	0	0.17	0.26	6.0	0
48. Veal chop, loin	60.00	1 av.	69.0	19.2	11.0	0	176	11.0	207	2.9	0	0	0.18	0.27	6.3	0
				11.5	6.6	0	106	7.0	124	1.7	0	0	0.108	0.162	3.78	0
49. Veal cutlet	70.00	1 av.	70.0	19.5	9.0	0	159	11.0	210	2.9	0	0	0.18	0.28	6.4	0
				13.7	6.3	0	111	8.0	147	2.0	0	0	0.126	0.196	4.48	0
Variety Meats:																
50. Bologna, all meat	30.00	1 oz., 2 thin sl.	62.4	14.8	15.9	3.6	217	9.0	160	2.2	0	0	0.31	0.30	3.0	0
				4.4	4.8	1.0	65	3.0	48	0.7	0	0	0.09	0.09	0.9	0
51. Frankfurters, all meat	60.00	1 av. 7 to 9 to 1 lb.	64.3	15.2	14.1	3.3	201	9.0	164	2.3	0	0	0.19	0.23	2.4	0
				9.1	8.5	1.9	121	6.0	98	1.4	0	0	0.114	0.138	1.5	0
[ 52. Hash, corned beef, canned 72% beef, 28% potato	100.00	3½ oz.	69.4	15.1	6.1	7.0	143	26.0	90	1.3	0	0	0.02	0.13	2.4	0
				15.1	6.1	7.0	143	26.0	90	1.3	0	0	0.02	0.13	2.4	0
53. Heart, fresh	100.00	3½ oz.	75.4	16.5	6.3	0.7	126	10.0	236	6.2	0	0	0.54	0.90	6.8	14.0
				16.5	6.3	0.7	126	10.0	236	6.2	0	0	0.54	0.90	6.8	14.0
54. Liver, fresh	60.00	1 sm. serv.	70.9	19.8	4.2	3.6	131	8.0	373	12.1	19,200	0.27	2.80	16.1	31.0	
				11.8	2.5	2.2	79	5.0	224	7.3	11,520	0.16	1.68	9.7	19.0	

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
55. Liver sausage	30.00	1 oz 1 sl. $\frac{1}{4}$ " thick	59.0	16.7 5.0	20.6 6.2	1.5 0.5	258 78	9.0 3.0	238 71	5.4 1.6	5,750 1,725	0.17 0.057	1.12 0.336	4.6 1.56	0 0
56. Tongue, fresh	60.00	1 sm. serv.	68.0	16.4 9.8	15.0 9.0	0.4 0	202 121	30.0 18.0	119 72	6.9 4.2	0 0	0.22 0.13	0.27 0.16	5.0 3.0	0 0
Poultry:															
57. Chicken, boned, canned	30.00	1 oz.	67.1	21.8 6.5	9.8 2.9	0 0	175 53	32.0 10.0	218 65	1.9 0.6	trace 0	0.01 0.003	0.15 0.045	3.7 1.11	2.0 0.6
58. Chicken, roasted	100.00	3 $\frac{1}{2}$ oz.	66.0	20.2 20.2	12.6 12.6	0 0	194 194	16.0 16.0	218 218	1.9 1.9	trace trace	0.11 0.11	0.18 0.18	8.6 8.6	0 0
59. Turkey	100.00	3 $\frac{1}{2}$ oz.	58.3	20.1 20.1	20.2 20.2	0 0	262 262	23.0 23.0	320 320	3.8 3.8	trace trace	0.12 0.12	0.19 0.19	7.9 7.9	0 0
Fish and Shellfish:															
60. Cod	100.00	3 $\frac{1}{2}$ oz.	82.6	16.5 16.5	0.4 0.4	0 0	70 70	18.0 18.0	189 189	0.9 0.9	0 0	0.04 0.04	0.05 0.05	2.3 2.3	2 2
61. Miscellaneous, medi- um fat	100.00	3 $\frac{1}{2}$ oz.	77.2	19.0 19.0	2.5 2.5	0 0	98 98	21.0 21.0	218 218	1.0 1.0	0 0	0.07 0.07	0.07 0.07	4.2 4.2	2 2
62. Oysters	100.00	4 to 6 med. raw	87.1	6.0 6.0	1.2 1.2	3.7 3.7	50 50	68.0 68.0	172 172	7.1 7.1	0 0	0.18 0.18	0.23 0.23	1.2 1.2	0 0

63. Salmon, canned, pink	60.00	67.4	20.6 12.4	9.6 5.8	0 0	169 102	67.0 40.0	286 172	1.3 0.8	80 48	0.03 0.020	0.18 0.108	0.5 3.9	0 0
64. Sardines, canned	30.00	57.4	25.7 7.7	11.0 3.3	1.2 0.4	207 62	35.0 11.0	365 110	1.8 0.5	290 87	0.06 0.018	0.12 0.036	5.2 1.6	0 0
65. Shrimp, canned	60.00	78.3	17.8 10.7	0.8 0.5	0.8 0.5	82 49	75.0 45.0	210 126	2.0 1.2	60 36	0.01 0.006	0.03 0.018	1.9 1.1	0 0
66. Tuna, canned	60.00	57.7	27.7 16.6	11.8 7.1	0 0	217 130	34.0 21.0	290 174	1.7 1.0	70 42	0.04 0.024	0.13 0.078	10.6 6.4	0 0
DRY BEANS, PEAS, NUTS														
67. Beans, canned, baked with tomatoes	100.00	71.0	5.7 5.7	2.0 2.0	19.0 19.0	117 117	49.0 49.0	154 154	3.4 3.4	70 70	0.05 0.05	0.05 0.05	0.8 0.8	4 4
68. Beans, dry seed, com- mon or kidney	30.00	10.5	22.0 6.6	1.5 0.45	62.1 18.6	350 105	148.0 45.0	463 139	10.3 3.1	0 0	0.60 0.18	0.24 0.07	2.1 0.63	2.0 0.6
69. Beans, lima, dry seed	30.00	12.6	20.7 6.2	1.3 0.4	61.6 18.5	341 103	68.0 21.0	381 115	7.5 2.2	0 0	0.60 0.180	0.24 0.07	2.1 0.63	2.0 0.6
70. Peas, split	30.00	10.0	24.5 7.4	1.0 0.3	61.7 18.5	354 106	73.0 22.0	397 119	6.0 1.8	370 111	0.87 0.26	0.29 0.09	3.0 0.9	2 0.6
71. Soy beans, whole ma- ture	30.00	7.5	34.9 10.5	18.1 5.4	12.0 4.0	351 106	227.0 68.0	586 176	8.0 2.4	110 33	1.14 0.34	0.31 0.09	2.1 0.63	trace 0
72. Almonds	15.00	4.7	18.6 2.8	54.1 8.1	19.6 2.9	640 96	254.0 38.0	475 71	4.4 0.6	0 0	0.25 0.038	0.67 0.10	4.6 0.69	trace 0
73. Peanut butter	15.00	1.7	26.1 3.9	47.8 7.2	21.0 3.2	619 93	74.0 11.0	393 59	1.9 0.3	0 0	0.20 0.030	0.16 0.024	16.2 2.43	0 0

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
74. Peanuts, roasted	15.00	16 to 17 nuts (no skin)	2.6	26.9	44.2	23.6	600	74.0	393	1.9	0	0.30	0.16	16.2	0
75. Pecans	15.00	12 halves	3.0	9.4 1.4	73.0 11.0	13.0 2.0	747 112	74.0 11.0	324 49	2.4 0.4	50 8	0.72 0.108	0.11 0.016	0.9 0.14	2.0 0.3
76. Walnuts, English	15.00	8 to 15 halves 1½ tbsp. chopped	3.3	15.0	64.4	15.6	702	83.0	380	2.1	30	0.48	0.13	1.2	3.0
FRESH VEGETABLES															
77. Asparagus, fresh	50.00	6 stalks, 4" long	93.0	2.2 1.1	0.2 0.1	3.9 2.0	26 13	21.0 11.0	62 31	0.9 0.5	1000 500	0.16 0.08	0.17 0.09	1.2 0.6	33.0 17.0
78. Beans, lima, green	100.00	½ c. or 4 tbsp.	66.5	7.5	0.8	23.5	131	63.0	158	2.3	280	0.25	0.14	0.9	32.0
79. Beans, snap	100.00	½ c., ckd.	88.9	2.4 2.4	0.2 0.2	7.7 7.7	42 42	65.0 65.0	44 44	1.1 1.1	630 630	0.08 0.08	0.10 0.10	0.6 0.6	19.0 19.0
80. Beet greens	100.00	½ c., ckd.	90.4	2.0 2.0	0.3 0.3	5.6 5.6	33 33	? ?	45 45	3.2 3.2	6700 6700	0.05 0.05	0.17 0.17	0.3 0.3	34.0 34.0
81. Beets	100.00	2 med.	87.6	1.6 1.6	0.1 0.1	9.6 9.6	46 46	27.0 27.0	43 43	1.0 1.0	20 20	0.03 0.03	0.05 0.05	0.4 0.4	10.0 10.0

	100.00	1 c. sc., ckd.	3.3	0.2	37	130.0	76	1.3	3,500	0.09	0.21	0.3	11.0
83. Brussels sprouts	70.00	6 av.	84.9	4.4 3.1	8.9 6.2	58 41	34.0 24.0	78 54	1.3 0.9	400 280	0.11 0.08	0.06 0.042	0.3 0.21
84. Cabbage	100.00 50.00	$\frac{3}{4}$ c. ckd. $\frac{1}{2}$ - $\frac{3}{4}$ c. raw	92.4	1.4 0.7	5.3 2.7	29 15	46.0 23.0	31 15	0.5 0.25	80 40	0.07 0.035	0.06 0.03	0.3 0.15
85. Carrots	100.00	1 lg., $\frac{2}{3}$ c. cubed	88.2	1.2 1.2	9.3 9.3	45 45	39.0 39.0	37 37	0.8 0.8	12,000 12,000	0.07 0.07	0.06 0.06	0.5 0.5
86. Cauliflower	70.00	4 tbsp.	91.7	2.4 1.7	4.9 3.4	31 22	22.0 16.0	72 50	1.1 0.8	90 63	0.10 0.07	0.11 0.08	0.6 0.42
87. Celery	50.00	2 stalks or hts.	93.7	1.3 0.7	3.7 1.9	22 11	50.0 25.0	40 20	0.5 0.3	0 0	0.03 0.015	0.04 0.02	0.3 0.15
88. Chard	100.00	$\frac{1}{2}$ c. ckd.	91.8	1.4 1.4	4.4 4.4	25 25	? ?	36 36	4.0 4.0	2800 2800	0.06 0.06	0.13 0.13	0.2 0.2
89. Collards	100.00	$\frac{1}{2}$ c. ckd.	86.6	3.9 3.9	7.2 7.2	50 50	249.0 249.0	58 58	1.6 1.6	6870 6870	0.22 0.22	0.20 0.20	0.8 0.8
90. Corn, sweet, white or yellow	100.00	1 med. ear	73.9	3.7 3.7	20.5 20.5	108 108	9.0 9.0	120 120	0.5 0.5	Tr. to 390	{0.15 0.15}	0.14 0.14	1.4 1.4
91. Cucumbers	50.00	$\frac{1}{2}$ med. 8sl. peeled	96.1	0.7 0.4	2.7 1.4	14 7	10.0 5.0	21 11	0.3 0.15	0 0	0.04 0.20	0.09 0.045	0.2 0.1
92. Dandelion greens	100.00	$\frac{1}{2}$ c. ckd.	85.8	2.7 2.7	8.8 8.8	52 52	187.0 187.0	70 70	3.1 3.1	13,650 13,650	0.19 0.19	0.14 0.14	0.8 0.8
93. Eggplant	100.00	$\frac{1}{2}$ c. ckd.	92.7	1.1 1.1	5.5 5.5	28 28	15.0 15.0	37 37	0.4 0.4	30 30	0.07 0.07	0.06 0.06	0.8 0.8

? May not be available because of the presence of oxalic acid.

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
94. Kale	100.00	$\frac{1}{2}$ c. ckd.	86.6	3.9 3.9	0.6 0.6	7.2 7.2	50 50	225.0 225.0	62 62	2.2 2.2	7540 7540	0.12 0.12	0.35 0.35	0.8 0.8	115.0 115.0
95. Lettuce, green varieties	50.00	5 lg. leaves	94.8	1.2 0.6	0.2 0.1	2.9 1.4	18 9	62.0 31.0	20 10	1.1 0.5	1620 810	0.06 0.03	0.07 0.03	0.2 0.1	18.0 9.0
96. Lettuce, headed	100.00	$\frac{1}{2}$ to $\frac{1}{4}$ head	94.8	1.2 1.2	0.2 0.2	2.9 2.9	18 18	22.0 22.0	25 25	0.5 0.5	540 540	0.06 0.06	0.07 0.07	0.2 0.2	8.0 8.0
97. Mustard greens	100.00	$\frac{1}{2}$ c. ckd.	92.2	2.3 2.3	0.3 0.3	4.0 4.0	28 28	220.0 220.0	38 38	2.9 2.9	6460 6460	0.09 0.09	0.20 0.20	0.8 0.8	102.0 102.0
98. Okra	50.00	5 to 6 pods	89.8	1.8 0.9	0.2 0.1	7.4 3.7	39 19	82.0 41.0	62 31	0.7 0.4	740 370	0.12 0.060	0.10 0.05	0.7 0.35	30.0 15.0
99. Onions, mature	100.00	2 to 3 sm.	87.5	1.4 1.4	0.2 0.2	10.3 10.3	49 49	32.0 32.0	44 44	0.5 0.5	50 50	0.03 0.03	0.02 0.02	0.1 0.1	9.0 9.0
100. Parsnips	100.00	$\frac{1}{2}$ lg.	78.6	1.5 1.5	0.5 0.5	18.2 18.2	83 83	57.0 57.0	80 80	0.7 0.7	0 0	0.11 0.11	0.09 0.09	0.2 0.2	18.0 18.0
101. Peas, green	100.00	$\frac{1}{2}$ c. sc.	74.3	6.7 6.7	0.4 0.4	17.7 17.7	101 101	22.0 22.0	122 122	1.9 1.9	680 680	0.36 0.36	0.18 0.18	2.1 2.1	26.0 26.0
102. Pepper, green	100.00	1 shell	92.4	1.2 1.2	0.2 0.2	5.7 5.7	29 29	11.0 11.0	25 25	0.4 0.4	630 630	0.07 0.07	0.04 0.04	0.4 0.4	120.0 120.0

103. Potatoes White	100.00 100.00	1 sm. av. 1 c. sc., 2 hp. tbsp.	77.8	2.0 2.0	0.1 0.1	19.1 19.1	85 85	11.0 11.0	56 56	0.7 0.7	20 20	0.11 0.11	0.04 0.04	1.2 1.2	17.0 17.0
104. Radishes	10.00	1" in diam.	93.6	1.2 0.1	0.1 0.0	4.2 0.4	22 2	37.0 4.0	31 3	1.0 0.1	30 3	0.04 0	0.04 0	0.1 0	24.0 2.0
105. Rutabagas	100.00	1 c. ckd.	89.1	1.1 1.1	0.1 0.1	8.9 8.9	41 41	55.0 55.0	41 41	0.4 0.4	330 330	0.06 0.06	0.06 0.06	0.5 0.5	36.0 36.0
106. Spinach	100.00	3 c. ckd.	92.7	2.3 2.3	0.3 0.3	3.2 3.2	25 25	? ?	55 55	3.0 3.0	9420 9420	0.12 0.12	0.24 0.24	0.7 0.7	59.0 59.0
107. Squash, summer	100.00	1 c. ckd.	95.0	0.6 0.6	0.1 0.1	3.9 3.9	19 19	15.0 15.0	15 15	0.4 0.4	260 260	0.04 0.04	0.05 0.05	1.1 1.1	17.0 17.0
108. Squash, winter	100.00	1 c. ckd.	88.6	1.5 1.5	0.3 0.3	8.8 8.8	44 44	19.0 19.0	28 28	0.6 0.6	4950 4950	0.05 0.05	0.08 0.08	0.6 0.6	8.0 8.0
109. Sweet potatoes	170.00	1 lg.	68.5	1.8 3.1	0.7 1.2	27.9 47.4	125 213	30.0 51.0	49 83	0.7 1.2	7,700 13,090	0.10 0.17	0.06 0.102	0.7 1.19	22.0 38.0
110. Tomatoes, red	100.00	1 med.	94.1	1.0 1.0	0.3 0.3	4.0 4.0	23 23	11.0 11.0	27 27	0.6 0.6	1100 1100	0.06 0.06	0.04 0.04	0.6 0.6	23.0 23.0
111. Turnip greens	100.00	1 c. ckd.	89.5	2.9 2.9	0.4 0.4	5.4 5.4	37 37	259.0 259.0	50 50	2.4 2.4	9540 9540	0.10 0.10	0.56 0.56	0.8 0.8	136.0 136.0
112. Turnips	100.00	1 c.	90.9	1.1 1.1	0.2 0.2	7.1 7.1	35 35	40.0 40.0	34 34	0.5 0.5	trace trace	0.06 0.06	0.06 0.06	0.5 0.5	28.0 28.0
CANNED VEGETABLES 113. Asparagus	50.00	4-5 sm. tips, drained	93.6	1.6	0.3	3.0	21	20.0	34	1.0	600	0.06	0.09	0.8	15.0
114. Beans, lima	100.00	1 c.	80.9	3.8 3.8	0.3 0.3	13.5 13.5	72 72	27.0 27.0	73 73	1.7 1.7	130 130	0.03 0.03	0.05 0.05	0.5 0.5	8.0 8.0

? May not be available because of the presence of oxalic acid.

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
115. Beans, snap	100.00	$\frac{1}{2}$ c. drained	94.0	1.0 1.0	0.0 0.0	3.8 3.8	19 19	27.0 27.0	19 19	1.4 1.4	410 410	0.03 0.03	0.05 0.05	0.3 0.3	4.0 4.0
116. Corn, white or yellow	100.00	$\frac{1}{2}$ c.	80.5	2.0 2.0	0.5 0.5	16.1 16.1	77 77	4.0 4.0	51 51	0.5 0.5	200 200	0.02 0.02	0.05 0.05	0.8 0.8	5.0 5.0
117. Peas, green	100.00	$\frac{1}{2}$ c. sc.	82.3	3.4 3.4	0.4 0.4	12.9 12.9	69 69	25.0 25.0	67 67	1.8 1.8	540 540	0.11 0.11	0.06 0.06	0.9 0.9	8.0 8.0
118. Sauerkraut	100.00	$\frac{2}{3}$ c.	93.2	1.1 1.1	0.2 0.2	3.4 3.4	20 20	46.0 46.0	31 31	0.5 0.5	trace trace	0.03 0.03	0.20 0.20	0.2 0.2	18.0 18.0
119. Spinach	100.00	$\frac{1}{2}$ c.	92.3	2.3 2.3	0.4 0.4	3.0 3.0	25 25	? ?	33 33	1.6 1.6	6790 6790	0.02 0.02	0.08 0.08	0.3 0.3	14.0 14.0
120. Tomato catsup	20.00	1 tbsp.	69.5	2.0 0.4	0.4 0.08	24.5 4.8	110 22	12.0 3.0	18 4	0.8 0.2	1880 376	0.09 0.018	0.07 0.014	2.2 0.44	11.0 2.0
121. Tomato juice	100.00	$\frac{1}{2}$ c.	93.5	1.0 1.0	0.2 0.2	4.3 4.3	23 23	7.0 7.0	15 15	0.4 0.4	1050 1050	0.05 0.05	0.03 0.03	0.7 0.7	16.0 16.0
122. Tomato purée	100.00	$\frac{1}{2}$ c.	89.2	1.8 1.8	0.5 0.5	7.2 7.2	40 40	11.0 11.0	37 37	1.1 1.1	1880 1880	0.09 0.09	0.07 0.07	1.8 1.8	28.0 28.0
123. Tomatoes	100.00	$\frac{1}{2}$ c.	94.2	1.0 1.0	0.2 0.2	3.9 3.9	21 21	11.0 11.0	27 27	0.6 0.6	1050 1050	0.05 0.05	0.03 0.03	0.7 0.7	16.0 16.0

## STRAINED OR CHOPPED\* VEGETABLES

124. Asparagus (Heinz)	28.35	1 oz. 2 level tbsp.	0.7	1.7	0.211	4.6	28	11.0	32	0.7	1390	0.07	0.112	17.0
				0.5	0.06	1.3	8	3.0	9	0.2	397	0.022	0.034	5.0
125. Beets (Heinz)	28.35	1 oz.		1.4	0.1	8.7	38	17.0	35	1.8	14	0.014	0.028	10.0
				0.4	0.03	2.4	11	5.0	10	0.5	4	0.004	0.008	3.0
126. Beans, green (Gerber)	28.35	1 oz. 2 level tbsp. chopped		1.4	0.10	4.2	25	28.0	24	1.0	605	0.024	0.072	7.0
				0.4	0.03	1.2	7	8.0	7	0.3	173	0.012	0.022	2.0
127. Beans, green (Heinz)	28.35	1 oz. strained		2.1	0.2	3.9	25	53.0	32	1.0	1190	0.039	0.077	7.0
				0.6	0.06	1.1	7	15.0	9	0.3	340	0.009	0.022	2.0
128. Carrots (Gerber)	28.35	1 oz. 2 level tbsp. chopped		0.7	0.39	5.6	28	25.0	25	1.4	5582	0.035	0.042	4.0
				0.2	0.06	1.6	8	7.0	7	0.4	3721	0.010	0.012	1.0
129. Carrots (Heinz)	28.35	1 oz. strained		1.0	0.21	5.6	28	28.0	28	1.0	6748	0.024	0.052	4.0
				0.3	0.06	1.6	8	8.0	8	0.3	1928	0.007	0.015	1.0
130. Greens, mixed (Heinz)	28.35	1 oz., strained		2.5	0.21	2.5	21	105.0	49	1.4	4168	0.039	0.119	18.0
				0.7	0.06	0.7	6	30.0	14	0.4	1191	0.011	0.034	5.0
131. Peas (Heinz)	28.35	1 oz., strained		4.9	0.49	8.8	59	11.0	84	1.8	1295	0.130	0.119	14.0
				1.4	0.14	2.5	17	3.0	24	0.5	370	0.037	0.034	4.0
132. Spinach (Gerber)	28.35	1 oz. 2 level tbsp. chopped		2.1	0.49	2.1	21	?	49	1.4	408	0.028	0.094	7.0
				0.6	0.14	0.6	6		14	0.4	1166	0.008	0.027	2.0
133. Spinach (Heinz)	28.35	1 oz., strained		2.4	0.49	1.4	21	?	39	1.0	5358	0.028	0.168	7.0
				0.7	0.14	0.4	6		11	0.3	1531	0.008	0.048	2.0

? May not be available because of the presence of oxalic acid.

\* Bowes and Church Food Values of Portions Commonly Used—household measure % composition is calculated.

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
134. Vegetable soup (Heinz)	28.35	1 oz. strained		1.7 0.5	0.1 0.03	8.8 2.5	42 12	25.0 7.0	25 7	1.0 0.3	1291 369	0.217 0.062	0.108 0.031		4.0 1.0
FRUIT, FRESH															
135. Apples	100.00 150.00	1 sm. 1 lg., 3"-4" india.	84.1	0.3 0.5	0.4 0.6	14.9 22.4	64 96	6.0 9.0	10 15	0.3 0.5	90 135	0.04 0.060	0.02 0.03	0.2 0.3	5.0 8.0
136. Apricots	100.00	2 to 3 med.	85.4	1.0 1.0	0.1 0.1	12.9 12.9	56 56	16.0 16.0	23 23	0.5 0.5	2790 2790	0.03 0.03	0.04 0.04	0.7 0.7	4.0 4.0
137. Avocado Fuerte	100.00	$\frac{1}{2}$ of a 4" pear	65.4	1.7 1.7	26.4 26.4	5.1 5.1	265 265	10.0 10.0	38 38	0.6 0.6	290 290	0.12 0.12	0.15 0.15	1.1 1.1	16.0 16.0
138. Banana	100.00	1 sm.	74.8	1.2 1.2	0.2 0.2	23.0 23.0	99 99	8.0 8.0	28 28	0.6 0.6	430 430	0.09 0.09	0.06 0.06	0.6 0.6	10.0 10.0
139. Blueberries	100.00	$\frac{2}{3}$ c.	83.4	0.6 0.6	0.6 0.6	15.1 15.1	68 68	16.0 16.0	13 13	0.8 0.8	280 280	0.03 0.03	0.07 0.07	0.3 0.3	16.0 16.0
140. Strawberries	100.00	10 lg.	90.0	0.8 0.8	0.6 0.6	8.1 8.1	41 41	28.0 28.0	27 27	0.8 0.8	60 60	0.03 0.03	0.07 0.07	0.3 0.3	60.0 60.0
141. Other berries	100.00	$\frac{2}{3}$ c.	84.4	1.2 1.2	0.8 0.8	13.2 13.2	65 65	36.0 36.0	34 34	0.9 0.9	320 320	0.03 0.03	0.07 0.07	0.3 0.3	23.0 23.0
142. Cantaloupe	150.00	$\frac{1}{2}$ of a 4 $\frac{1}{2}$ " melon	94.0	0.6 0.9	0.2 0.3	4.6 6.9	23 35	17.0 26.0	16 24	0.4 0.6	3420 5130	0.06 0.09	0.04 0.06	0.8 1.1	33.0 49.0

143. Grapefruit	100.00	$\frac{1}{2}$ sm.	88.8	0.5	0.2	10.1	44	17.0	18	0.3	trace	0.04	0.02	0.2	40.0
				0.5	0.2	10.1	44	17.0	18	0.3	trace	0.04	0.02	0.2	40.0
144. Grapes, Malaya or Tokay	100.00	22	81.6	0.8	0.4	16.7	74	17.0	21	0.6	80	0.05	0.03	0.4	4.0
				0.8	0.4	16.7	74	17.0	21	0.6	80	0.05	0.03	0.4	4.0
145. Lemon	100.00	1 med.	89.3	0.9	0.6	8.7	44	14.0	10	0.1	0	0.04	trace	0.1	45.0
				0.9	0.6	8.7	44	14.0	10	0.1	0	0.04	trace	0.1	45.0
146. Orange, whole	100.00	1 sm.	87.2	0.9	0.2	11.2	50	33.0	23	0.4	190	0.08	0.03	0.2	49.0
				0.9	0.2	11.2	50	33.0	23	0.4	190	0.08	0.05	0.2	49.0
147. Peach	100.00	1 med. lg.	86.9	0.5	0.1	12.0	51	8.0	22	0.6	880	0.02	0.05	0.9	8.0
				0.5	0.1	12.0	51	8.0	22	0.6	880	0.02	0.05	0.9	8.0
148. Pear	100.00	1 med.	82.7	0.7	0.4	15.8	70	13.0	16	0.3	20	0.02	0.04	0.1	4.0
				0.7	0.4	15.8	70	13.0	16	0.3	20	0.02	0.04	0.1	4.0
149. Pineapple	100.00	$\frac{1}{2}$ to $\frac{2}{3}$ c.	85.3	0.4	0.2	13.7	58	16.0	11	0.3	130	0.08	0.02	0.2	24.0
				0.4	0.2	13.7	58	16.0	11	0.3	130	0.08	0.02	0.2	24.0
150. Plums	100.00	3 med.	85.7	0.7	0.2	12.9	56	17.0	20	0.5	350	0.15	0.03	0.6	5.0
				0.7	0.2	12.9	56	17.0	20	0.5	350	0.15	0.03	0.6	5.0
151. Rhubarb	100.00	1 c. cubes	94.9	0.5	0.1	3.8	18	?	25	0.5	30	0.01		0.1	9.0
				0.5	0.1	3.8	18	?	25	0.5	30	0.01		0.1	9.0
152. Tangerines	100.00	1 lg. or 2 sm.	87.3	0.8	0.3	10.9	50	33.0	23	0.4	420	0.07	0.03	0.2	31.0
				0.8	0.3	10.9	50	33.0	23	0.4	420	0.07	0.03	0.2	31.0
153. Watermelon	600.00	1 sl., 6" in diam. by 1 $\frac{1}{2}$ "	92.1	0.5	0.2	6.9	31	7.0	12	0.2	590	0.05	0.05	0.2	6.0
				3.0	1.2	41.4	186	42.0	72	1.2	3540	0.3	0.3	1.2	36.0

? May not be available because of the presence of oxalic acid.

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
FRUIT, CANNED*	100.00	½ c., sc.	79.8	0.2	0.1	19.7	80	4.0	6	0.2	60	0.01	0.01	trace	1.0
	100.00	½ c., sc.		0.2	0.2	10.9	46	4.0	6	0.2	50	0.01	0.020	0.04	1.0
155. Apricots, in syrup water pack	100.00	6 hal., 3 tbsp. j.	77.3	0.6	0.1	21.4	89	10.0	15	0.3	1350	0.02	0.02	0.3	4.0
	100.00	6 hal., 3 tbsp. j.		0.5	0.1	8.1	35	10.0	15	0.3	1350	0.02	0.02	0.33	4.0
156. Cherries juice pack	100.00	½ c. or 12 lg.	78.1	0.6	0.1	20.8	86	11.0	14	0.3	430	0.03	0.02	0.2	3.0
	100.00	½ c. black		0.7	0.3	18.0	78	11.0	14	0.3	430	0.03	0.02	0.08	3.0
157. Cranberry sauce	20.00	1 tbsp.	48.1	0.1	0.3	51.4	209	8.0	7	0.3	30		0.04		2.0
				0.02	0.06	10.2	42	2.0	1	0.06	6				1.0
158. Grapefruit juice	100.00	3½ oz., unsweet- ened	89.4	0.5	0.2	9.4	41	8.0	12	0.4	trace	0.03	0.02	0.2	35.0
				0.5	0.2	9.4	41	8.0	12	0.4	trace	0.03	0.02	0.2	35.0
159. Orange juice	100.00	3½ oz., ½ c. sc.	86.0	0.6	0.1	12.9	55	33.0	23	0.4	100	0.07	0.02	0.2	42.0
				0.6	0.1	12.9	55	33.0	23	0.4	100	0.07	0.02	0.2	42.0
160. Pineapple juice	100.00	3½ oz., ½ c. sc.	86.2	0.3	0.1	13.0	54	15.0	8	0.5	80	0.05	0.02	0.2	9.0
				0.3	0.1	13.0	54	15.0	8	0.5	80	0.05	0.02	0.2	9.0
161. Peaches water pack	100.00	2 hal., 1 tbsp. j.	80.9	0.4	0.1	18.2	75	5.0	14	0.4	450	0.01	0.02	0.7	4.0
				0.5	0.1	6.8	30	5.0	14	0.4	450	0.01	0.02	0.7	4.0

162. Pears water pack	100.00	2 hal., 1 tbsp. j. 2 hal., 1 tbsp. j.	81.1	0.2 0.3	0.1 0.1	18.4 8.2	75 35	8.0 8.0	10 10	0.2 0.2	trace trace	0.01 0.01	0.02 0.02	0.1 0.1	2.0 2.0
163. Pineapple, in syrup juice pack	100.00 100.00	1 sl. $\frac{3}{4}$ " thick 1 sl. $\frac{3}{4}$ " thick	78.0	0.4 0.4	0.1 0.1	21.1 14.5	87 60	10.0 10.0	7 7	0.6 0.6	80 80	0.07 0.07	0.02 6.02	0.2 0.29	9.0 10.0
164. Plums, in syrup water pack		2 med. 1 to 2 tbsp. j. 2 med. 2 tbsp. j.	78.6	0.4 0.4	0.1 0.1	20.4 7.2	84 31	8.0 8.0	12 12	1.1 1.1	230 230	0.03 0.03	0.03 0.03	0.4 0.4	1.0 1.0
FRUITS, DRIED 165. Apricots			24.0	5.2 1.6	0.4 0.1	66.9 20.0	292 88	86.0 26.0	119 36	4.9 1.5	7430 2229	0.01 0.003	0.16 0.05	3.3 0.1	12.0 4.0
166. Peaches (sulfured)	30.00	4 to 6 halves													
	30.00	2 halves	24.0	3.0 0.9	0.6 0.2	69.4 20.8	295 89	44.0 13.0	126 38	6.9 2.0	3250 975	0.01 0.003	0.20 0.06	5.4 1.62	19.0 6.0
167. Prunes (unsulfured)	30.00	2 to 3 med.	24.0	2.3 0.7	0.6 0.2	71.0 21.3	299 88	54.0 16.0	85 26	3.9 1.2	1890 567	0.10 0.03	0.16 0.05	1.7 0.5	3.0 1.0
FRUITS, STRAINED † 168. Apricots and apples	100.00	$\frac{1}{2}$ c. Heinz		0.6 0.6	0.1 0.1	14.4 14.4	61 61	12.0 12.0	19 19	1.3 1.3	4100 4100	0.021 0.021	0.045 0.045		2.0 2.0
169. Pears and pineapples	100.00	$\frac{1}{2}$ c. Heinz		0.4 0.4	0.4 0.4	12.9 12.9	57 57	13.0 13.0	10 10	1.3 1.3	170 170	0.036 0.036	0.043 0.043		2.0 2.0
170. Prunes	100.00	$\frac{1}{2}$ c. Gerbers		0.8 0.8	0.3 0.3	22.6 22.6	96 96	21.0 21.0	17 17	3.4 3.4	821 821	0.028 0.028	0.059 0.059		4.0 4.0
FLOUR MEAL 171. Cornmeal, white whole grain	20.00	$\frac{1}{2}$ c. ckd.	12.0	9.1 1.8	3.7 0.74	73.9 15.0	365 73	18.0 4.0	248 50	2.7 0.54	0 0	0.41 0.08	0.12 0.02	1.7 0.3	0 0

\* Water and juice pack canned fruit—Bowes and Church.

† Bowes and Church Food Values of Portions Commonly Used—household measure % composition is calculated.

TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
172. Cornmeal, yellow whole grain	20.00	$\frac{1}{2}$ c. ckd.	12.0	9.1 1.8	3.7 0.74	73.9 15.0	365 73	18.0 4.0	276 55	2.7 0.54	510 102	0.45 0.09	0.17 0.03	2.1 0.04	0 0
173. Cornstarch	10.00	1 tbsp.	12.0	0.5	0.2	87.0 9.0	352 35	trace 0	trace 0	trace 0	0 0	0 0	0 0	0 0	0 0
<sup>23</sup> FLOUR															
174. Wheat, patent enriched	100.00 8.00	$\frac{3}{4}$ c. 1 tbsp.	12.0	10.8 0.9	0.9 0.07	75.9 6.0	355 28	19.0 2.0	93 8	2.9 0.23	0 0	0.44 0.03	0.26 0.02	3.5 0.28	0 0
175. Whole wheat	100.00 10.00	$\frac{3}{4}$ c. 1 tbsp.	11.0	13.0 1.3	2.0 0.2	72.4 7.3	360 36	38.0 4.0	385 39	3.8 0.38	0 0	0.56 0.06	0.12 0.012	5.6 0.6	0 0
BREAD, CRACKERS															
176. Rye, light	30.00	1 sl.	37.6	6.4 1.9	3.4 0.9	51.7 16.0	263 79	22.0 7.0	96 29	0.8 0.3	0 0	0.16 0.05	0.04 0.01	1.1 0.4	0 0
177. White, enriched	25.00	1 sl. av.	35.9	8.5 2.1	2.0 0.5	52.3 13.0	261 65	56.0 14.0	100 25	1.8 0.5	0	0.24 0.06	0.15 0.037	2.2 0.05	0 0
178. Whole wheat	28.00	1 sl. av.	37.0	9.5 2.7	3.5 1.0	48.0 14.0	262 74	60.0 17.0	370 104	2.6 0.7	0	0.28 0.08	0.15 0.04	3.5 0.90	0 0
179. Rolls, plain, enriched	30.00	1 Parkerhouse	29.4	8.2 2.5	6.1 1.8	54.1 16.0	304 91	56.0 17.0	100 30	1.8 0.6	0 0	0.24 0.07	0.15 0.05	2.2 0.7	0 0

181. Crackers, graham	6.00	1, 2 1/2" x 2 1/4"	5.5	8.0	10.0	74.3	419	20.0	203	1.9	0	0.30	0.12	1.5	0
	10.00	1, 2 1/2" x 2 3/4"		0.8	1.0	7.0	42	2.0	20	0.2	0	0.03	0.01	0.15	0
CEREALS															
182. Corn flakes	20.00	1 c.	9.3	7.9	0.7	80.3	359	10.0	56	1.0	0	0.16	0.08	1.6	0
				1.6	0.1	16.0	72	2.0	11	0.2	0	0.03	0.02	0.3	0
183. Oatmeal	20.00	1/2 c. ckd.	8.3	14.2	7.4	68.2	396	54.0	365	5.2	0	0.55	0.14	1.1	0
				2.9	1.5	13.7	79	11.0	73	1.0	0	0.11	0.03	0.22	0
184. Rice flakes, puffed	10.00	3/4 c.	8.8	7.2	0.4	82.6	363	9.0	92	0.9	0	0.05	0.03	1.4	0
				0.7	0.04	8.5	36	1.0	9	0.09	0	0.005	0.003	0.14	0
CEREALS, WHEAT PREPARATIONS															
185. Farina	20.00	1 c. ckd.	11.0	11.5	1.0	76.1	359	21.0	125	0.8	0	0.06	0.06	1.0	0
				2.3	0.2	15.2	72	4.0	25	0.16	0	0.012	0.012	0.2	0
186. Farina, enriched	20.00	1/2 c. ckd.	11.0	11.5	1.0	76.1	359	21.0	125	1.3	0	0.37	0.26	1.3	0
				2.3	0.2	15.2	72	4.0	25	0.26	0	0.08	0.05	0.26	0
187. Flakes, puffed	10.00	1 c. sc.	6.2	11.9	1.5	77.7	372	33.0	353	3.7	0	0.15	0.12	4.2	0
				1.2	0.15	7.8	37	3.0	35	0.4	0	0.015	0.012	0.4	0
188. Shredded wheat	30.00	1 biscuit	7.7	10.4	1.4	78.7	369	38.0	385	3.8	0	0.20	0.14	4.2	0
				3.1	0.4	24.0	111	12.0	116	1.2	0	0.06	0.04	1.3	0
189. Whole grain wheat, uncooked	20.00	1/2 c. ckd.	8.7	11.7	2.0	75.8	368	38.0	385	3.8	0	0.45	0.13	4.6	0
				2.3	0.4	15.2	74	8.0	77	0.8	0	0.09	0.03	0.9	0
OTHER CEREALS															
190. Barley, pearled, light	14.00	1 tbsp., 1/4 c. ckd.	11.1	8.2	1.0	78.8	357	16.0	189	2.0	0	0.12	0.08	3.1	0
				1.2	0.14	11.0	50	2.0	27	0.3	0	0.02	0.01	0.4	0

TABLE 384—Continued

Food	Wt. (gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Fat (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Vitamins				
										Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
191. Hominy	20.00	$\frac{1}{2}$ c., sc.	11.4	8.5 1.7	0.8 0.16	78.9 15.8	357 71	11.0 2.0	70 14	0 0	0.15 0.03	0.05 0.01	0.9 0.2	0 0
192. Macaroni, spaghetti	20.00	$\frac{1}{2}$ c. ckd.	11.0	13.0 2.6	1.4 0.3	73.9 14.8	360 72	22.0 4.0	144 29	0 0	0.13 0.03	0.08 0.02	2.1 0.4	0 0
193. Noodles	20.00	$\frac{1}{2}$ c. ckd.	9.1	14.3 2.9	5.0 1.0	70.6 14.1	385 77	24.0 5.0	156 31	200 40	0.13 0.03	0.12 0.03	2.1 0.4	0 0
194. Rice, brown	20.00	$\frac{1}{2}$ c. ckd.	12.0	7.5 1.5	1.7 0.3	77.7 15.6	356 71	39.0 8.0	303 61	0 0	0.29 0.06	0.05 0.01	4.6 0.9	0 0
195. Rice, white	20.00	$\frac{1}{2}$ c. ckd.	12.3	7.6 1.5	0.3 0.06	79.4 15.8	351 70	9.0 2.0	92 18	0 0	0.05 0.01	0.03 —	1.4 0.3	0 —
196. Tapioca	15.00	1 tbsp.	12.6	0.6 0.1	0.2 0.03	86.4 12.9	350 52	12.0 2.0	12 2	0 0	0 0	0 0	0 0	0 0
SUGARS, SWEETS														
197. Honey	20.00	1 tbsp.	20.0	0.3 —	0 0	79.5 15.9	319 64	5.0 1.0	16 3	0 0	trace trace	0.04 —	0.2 —	4 1
198. Jam, marmalades	20.00	1 level tbsp.	28.0	0.5 0.1	0.3 0.06	70.8 14.2	288 58	12.0 2.0	12 2	10 2	0.02 —	0.02 —	0.2 —	0 1
199. Jellies	20.00	1 level tbsp.	34.5	0.2 —	0 0	65.0 13.0	261 52	12.0 2.0	12 2	10 2	0.02 —	0.02 —	0.2 —	4 1



TABLE 384—Continued

Food	Wt. (Gm.)	Household Measure	Water (Per Cent)	Pro- tein (Gm.)	Alco- hol (Gm.)	CHO (Gm.)	Calo- ries	Ca (Mg.)	P (Mg.)	Fe (Mg.)	Vitamins				
											Vita- min A (I.U.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)	Ascor- bic Acid (Mg.)
215. Cider, fermented	180.00	1 glass, 6 oz.			9.4	1.8	74								
216. Cider, sweet	180.00	1 glass, 6 oz.			0.2	18.9	77								
217. Ginger ale	180.00	1 m. glass, 6 oz.		—	—	16.2	65								
	240.00	1 lg. glass, 8 oz.		—	—	21.6	86								
218. Coca-Cola	180.00	1 bottle, 6 oz.		—	—	20.4	82								
219. Curacao	20.00	1 cordial glass			6.0	4.0	59								
220. Creme de Menthe	20.00	1 cordial glass			6.0	7.0	70								
221. Gin	43.00	1 jigger, 1½ oz.			15.1		107								
222. Rum	43.00	1 jigger, 1½ oz.			15.1		107								
223. Whiskey	43.00	1 jigger, 1½ oz.			17.2		122								
224. Wine, California, red	100.00	1 wine glass		0.2	10.0	0.5	74	9.0	15	0.3					
225. Wine, California, white	100.00	1 wine glass		0.2	10.5	0.5	74	9.0	15	0.3					
226. Wine, Champagne	135.00	1 champ. glass		0.3	14.9	4.1	123								
227. Wine, port	30.00	1 sherry glass		0.1	4.5	4.2	49								
228. Wine, sherry	30.00	1 sherry glass		0.1	4.5	2.4	42								
229. Wine, tokay	30.00	1 sherry glass		0.1	3.0	3.6	36								

TABLE 385

MINERAL COMPONENTS IN 100 GRAMS OF THE EDIBLE PORTIONS OF FOODS\*

<i>Food Items</i>	<i>Magne- sium (Gm.)</i>	<i>Potas- sium (Gm.)</i>	<i>Sodi- um (Gm.)</i>	<i>Chlo- rine (Gm.)</i>	<i>Sulfur (Gm.)</i>	<i>Copper (Mg.)</i>	<i>Man- gane- se (Mg.)</i>
nds.....	0.252	0.759	0.003	0.020	0.150		
s.....	0.006	0.116	0.002	0.004	0.005	0.071	0.084
ots, fresh.....	0.009	0.279	0.001	0.002	0.006		
okes, French.....	0.027	?	0.004	0.057	0.020		
ragus.....	0.012	0.187	0.003	0.036	0.046	0.141	0.190
ado.....	0.041	0.653	?	0.016	0.037	0.688	0.291
n, 10-15 per cent protein.....	0.013	0.239	0.820	1.251	0.152		
na.....	0.031	0.373	0.002	0.125	0.012	0.200	0.642
y, entire.....	0.171	0.485	?	?	0.143	0.753	1.684
pearled.....	0.037	0.110	0.003	?	0.116		
s, dried.....	0.159	1.201	?	0.035	0.237	0.957	1.503
Lima, dried.....	0.181	1.727	?	0.031	0.178	0.915	1.655
Snap or string.....	0.026	0.251	0.003	0.033	0.030	0.126	0.326
lean.....	0.024	0.338	0.084	0.076	0.230		
s.....	0.023	0.336	0.068	0.061	0.017	0.187	0.577
berries, seeds included.....	0.024	0.181	0.004	0.015	0.017		
Seeds removed.....	...	...	0.002	0.007	0.008		
berries.....	0.010	0.065	†	0.008	0.011		
ish.....	0.031	0.351	0.068	0.076	0.241		
il nuts.....	0.225	0.601	0.016	0.081	0.198		
d, white.....	0.030	0.109	0.446	0.621	0.054	0.205	0.310
Whole wheat.....	0.150	0.450	...	...	0.150		
coli.....	0.029	0.395	0.017	0.097	0.145		
Flower-buds.....	0.031	0.408	0.024				
Leaves.....	0.041	0.374	0.064				
Twigs.....	0.021	0.361	0.031				
sels sprouts.....	...	...	0.009	...	0.184		
er.....	0.001	0.014	0.220	0.330	0.009		
age, headed.....	0.012	0.294	0.018	0.039	0.067	0.099	0.114
Loose or outer leaves or greens.....	0.034	0.402	0.018	0.108	0.070		
caloupe.....	0.017	0.249	0.015	0.040	0.015	0.057	0.042
ots.....	0.017	0.311	0.048	0.042	0.021	0.111	0.247
ew nuts.....	0.267	†	†	†	†		
iflower.....	0.020	0.313	0.024	0.031	0.085		
y.....	0.027	0.291	0.096	0.137	0.022		
d.....	0.053	0.318	0.086	0.039	0.124		
se, hard.....	0.042	0.131	0.880	1.350	0.218		
ries.....	0.014	0.246	0.003	0.003	0.008		
tnuts.....	0.042	0.529	0.007	0.011	0.048		
ken (fowl).....	0.027	0.372	0.075	0.079	0.252		
colate.....	?	0.442	?	0.071	0.095		
as.....	0.089	0.172	0.603	1.065	0.219		
a.....	0.420	0.900	?	0.051	0.203		
nut, dried.....	0.077	0.693	0.053	0.225	0.076		
Fresh.....	0.039	0.363	0.039	0.122	0.032		
Milk.....	?	?	0.058	0.190	0.032		
ish.....	0.022	0.339	0.096	0.150	0.203		

\* From H. C. Sherman: Chemistry of Food and Nutrition, 7th ed. Copyright, 1946, by Macmillan Company and used with their permission (corrected 1949).

† For general computation, the data presented may be used with reasonable confidence, especially when dealing with food supplies obtained in markets that draw from widespread sources.

‡ Doubtless present, but quantitative data have not been found.

TABLE 385—Continued

<i>Food Items</i>	<i>Magne- sium (Gm.)</i>	<i>Potas- sium (Gm.)</i>	<i>Sodi- um (Gm.)</i>	<i>Chlo- rine (Gm.)</i>	<i>Sulfur (Gm.)</i>	<i>Copper (Mg.)</i>	<i>M g</i>
Conch.....	0.246	....	†	....	0.315		
Corn, maize.....	0.121	0.339	0.036	0.045	0.151	0.449	0.2
Meal.....	0.084	0.213	?	0.146	0.111		
Sweet.....	0.038	0.113	?	0.014	0.046		
Cranberries.....	0.007	0.080	0.006	0.005	0.007		
Cream.....	0.010	0.130	0.030	0.080	0.030		
Cucumbers, seeds included.....	0.009	0.140	?	0.030	0.012		
Currants, dried.....	0.030	0.458	0.018	0.029	?		
Fresh.....	0.015	0.261	0.002	0.013	0.029		
Juice.....	0.010	0.185	0.006	0.004	0.005		
Dandelion.....	0.036	0.461	?	0.099	0.170		
Dates.....	0.065	0.675	?	0.283	0.065		
Eggplant.....	0.015	0.229	0.002	0.047	0.021		
Eggs.....	0.013	0.138	0.140	0.120	0.197	0.253	0.0
Egg white.....	0.011	0.154	0.170	0.161	0.208		
Yolk.....	0.016	0.118	0.056	0.124	0.194		
Endive and Escarole.....	0.013	0.381	0.010	0.071	0.032		
Farina.....	0.025	0.120	?	0.076	0.155		
Figs, dried.....	0.082	0.990	?	0.105	0.069		
Fresh.....	0.021	0.297	?	0.016	0.012		
Fish, per 100 gm. protein.....	0.133	1.671	0.373	0.528	1.119		
Flounder.....	0.025	0.311	0.107	0.151	0.217		
Flour, buckwheat.....	0.048	0.130	?	0.012	0.071		
Graham or entire wheat.....	0.122	0.324	?	0.177	0.124	0.435	4.28
White.....	0.021	0.130	?	0.071	0.109	0.147	0.71
Gooseberries.....	0.009	0.149	0.001	0.009	0.015		
Grapefruit.....	0.010	0.198	0.002	0.003	0.008		
Juice.....	0.008	0.139	0.002	0.002	0.005		
Grapes.....	0.007	0.254	0.002	0.002	0.009	0.098	0.08
Haddeek.....	0.026	0.314	0.660	1.070	0.238	0.216	0.01
Halibut.....	0.024	0.340	0.083	0.088	0.212	0.160	0.01
Ham, medium lean.....	0.020	0.383	Varies	Varies	0.225		
Hazelnuts.....	0.140	0.618	0.019	0.067	0.198		
Heart.....	0.035	0.370	0.071	0.125	0.296		
Hominy.....	0.058	0.174	?	0.046	?		
Honey.....	0.006	?	0.005	0.019	0.005	0.075	0.20
Huckleberries.....	0.010	0.065	0.016	0.008	0.011		
Kale.....	0.037	0.387	0.056	0.122	0.115	0.328	0.58
Kidney.....	0.021	0.238	0.230	0.246	0.190		
Kohlrabi.....	0.037	0.371	0.050	0.053	0.050		
Lamb mutton.....	0.024	0.301	0.084	0.085	0.211		
Lemon (or juice).....	0.009	0.148	0.002	0.004	0.008		
Lentils, dry.....	0.086	0.835	0.057	0.060	0.277		
Lettuce.....	0.011	0.311	0.014	0.073	0.018	0.069	0.77
Liver.....	0.022	0.298	0.087	0.101	0.251	3.451	0.34
Loganberries, fresh and canned.....	0.018	0.177	0.002	0.011	0.011		
Macaroni.....	0.034	0.174	0.012	0.052	0.146		
Mackerel.....	0.033	0.418	0.153	0.152	0.197	0.230	0.02
Maple syrup.....	0.019	0.242	0.011	0.028	0.004		
Meat per 100 Gm. protein.....	0.118	1.694	0.421	0.378	1.146		
Milk, cow's.....	0.012	0.143	0.051	0.106	0.034	0.035	0.00
Molasses, old fashioned.....	0.081	1.238	0.043	0.501	0.050		
Mushrooms.....	0.016	0.384	0.007	0.021	0.051		
Muskmelon.....	0.017	0.249	?	0.040	0.015		
Mutton.....	0.024	0.301	0.084	0.085	0.211		
Oatmeal (cats).....	0.145	0.431	?	0.049	0.199	0.738	4.94

TABLE 385—Continued

<i>Food Items</i>	<i>Magne- sium (Gm.)</i>	<i>Potas- sium (Gm.)</i>	<i>Sodi- um (Gm.)</i>	<i>Chlo- rine (Gm.)</i>	<i>Sulfur (Gm.)</i>	<i>Copper (Mg.)</i>	<i>Man- ganese (Mg.)</i>
seeds incl. ....	0.038				0.014		
seeds removed. ....	0.043						
s. pickled in brine. ....	0.012	0.809	1.189	1.877	0.032		
s. ....	0.015	0.183	0.007	0.024	0.068	0.130	0.363
te or juice. ....	0.010	0.181	0.002	0.004	0.008	0.076	0.025
rs. ....	0.039	0.204	0.471	0.628	0.180	3.623	0.295
ips. ....	0.029	0.417	0.008	0.035	0.026		
oz. ....	0.011	0.256	0.004	0.005	0.007		
ats. ....	0.167	0.614	?	0.041	0.226		
	0.009	0.129	0.003	0.004	0.007	0.134	0.064
dry. ....	0.140	0.979	?	0.044	0.196	0.8022	1.990
fresh. ....	0.027	0.284	?	0.033	0.056		
es. ....	0.152	...	...	0.050	0.113		
er, green. ....	0.012	0.186	...	0.019	0.019	0.107	0.126
nmmons. ....	0.009	0.292	0.006	0.002	0.005		
pple. ....	0.011	0.214	0.002	0.046	0.007		
s. ....	0.011	0.232	0.004	0.002	0.005	0.080	0.096
medium lean. ....	0.024	0.304	0.069	0.069	0.206		
0 per cent protein. ....	0.012	0.169	0.042	0.038	0.115		
oes. ....	0.027	0.496	0.005	0.035	0.029	0.164	0.173
es, dry. ....	0.040	0.848	0.008	0.009	0.028	0.291	0.436
okins. ....	0.012	0.457	0.001	0.049	0.013		
shes. ....	0.015	0.229	?	0.037	0.031		
ns. ....	0.035	0.708	0.031	0.045	0.042		
berries, seeds included. ....	0.023	0.190	0.003	0.022	0.018		
Seeds removed. ....	0.020	0.140	0.003	...	0.010		
Juice. ....	0.016	0.134	0.005	...	0.009		
arb. ....	0.016	0.358	0.002	0.053	0.008		
entire. ....	0.119	0.342	?	0.023	?		
White. ....	0.028	0.079	?	0.006	?	0.183	1.014
entire. ....	0.155	0.450	0.061	0.040	0.146	0.656	3.067
Flour. ....	0.081	0.450	0.019	0.040	0.134		
on. ....	0.029	0.316	?	?	0.226		
nps. ....	0.074	0.404	Varies	Varies	?		
os, average. ....	0.010	0.240	?	0.042	?		
ean flower. ....	0.223	?	?	0.024	0.300		
ach. ....	0.055	0.489	0.084	0.065	0.027	0.197	0.828
sh, summer, seeds removed. ....	0.008	0.150	0.001				
Winter, seeds removed. ....	0.011	0.320	0.001				
wberries. ....	0.012	0.145	0.002	0.011	0.012	0.075	0.219
t potato. ....	0.024	0.373	?	0.085	0.026	0.184	0.407
cca. ....	0.002	0.020	0.004	0.016	0.004		
atoes, seeds included. ....	0.012	0.268	0.004	0.040	0.014	0.097	0.189
Seeds removed. ....	0.010	0.229	0.004	0.040	0.008		
Juice. ....	0.010	0.310	0.015	0.055	0.005		
key. ....	0.028	0.367	?	0.123	0.234		
ips. ....	0.016	0.327	?	0.052	0.058	0.085	0.083
Tops. ....	0.019	0.307	?	0.092	0.054		
, medium lean. ....	0.023	0.359	?	0.077	0.203		
gar. ....	0.011	0.150	?	0.047	0.018		
must. ....	0.134	0.525	0.004	0.036	0.146		
ercress. ....	0.028	0.301	?	0.109	0.147		
ermelon. ....	0.010	0.121	?	0.008	0.009		
at, entire. ....	0.165	0.465	0.006	0.049	0.171	0.787	4.591
e (average). ....	0.007	0.104	0.007	0.002	0.015		

† Doubtless present, but quantitative data have not been found.

The values for the sodium and potassium content of foods in Table 2 were obtained by conventional methods of chemical analysis. Since in many of these methods small amounts of potassium tend to be analyzed as sodium, the sodium values in many instances may be too high. Tables 385a and 385b give the values of the sodium and potassium contents of foods and water supplies analyzed by means of the flame photometer by Mead Johnson and Company. These analyses may be more accurate.

TABLE 385a  
SODIUM AND POTASSIUM CONTENTS OF FOOD  
(Mead Johnson and Co.)<sup>4a</sup>

Food*	Na, mg. per 100 Gm.	K, mg. per 100 Gm.	Food	Na, mg. per 100 Gm.	K, mg. per 100 Gm.
Allspice, ground.....	62	680	Bread, low sodium, (made with Lonalac)....	2	120
Almond.....	2	690	Cinnamon roll.....	2	120
Roasted in oil and salted.....	160	710	Passover. See <i>matzoth</i> .		
Anchovy paste.....	12,000	1900	Rye and wheat.....	560	100
Apple juice (sweet cider), bottled.....	4	100	Semi-wholewheat.....	670	300
Apple, less skin.....	0.1	68	Wheat, white.....	670	130
Applesauce, canned.....	0.3	55	Wholewheat.....	430	210
Apricot.....	0.5	440	Broccoli.....	16	400
Canned in sirup.....	2	65	Brussels sprouts.....	11	450
Asparagus, spears, canned.....	400	130	Frozen.....	9	300
Tips.....	2	240	Butter, average salted. Theoretical value based on U.S. aver- salt content of 2.5%...	980	
Frozen.....	3	320	Lightly salted.....	780	16
Avocado.....	2	340	Unsalted.....	5	4
Bacon.....	760	95	Buttermilk, cultured.....	130	140
Fried crisp.....	3200	450	Cabbage.....	5	230
Banana.....	0.1	400	Cantaloupe.....	12	230
Barley, pearled.....	3	160	Caraway seed.....	16	1400
Bean, Great Northern, dry.....	0.3	1400	Carrot.....	31	410
Green.....	0.8	300	Canned.....	280	110
Canned.....	410	120	Cashew nut.....	13	560
Frozen.....	2	110	Roasted in oil and salt...	200	560
Lima.....	1	680	Catchup, tomato.....	1300	800
Canned.....	310	210	Catfish (fiddler).....	60	330
Navy, dry.....	0.9	1300	Cauliflower, bud.....	24	400
Beef, corned.....	1700	400	Frozen.....	22	290
Dried.....	3900	1000	Caviar, salmon.....	2200	640
Less excess fat.....	53	380	Celery salt.....	26,000	3100
Beer.....	8	46	Seed.....	140	1400
Beet.....	110	350	Stalks.....	110	300
Canned.....	36	120	Cereal, bran.....	1400	1200
Leaves.....	130	570	Wheat, Instant Ral- ston.....	1	360
Blackberry.....	0.2	150	Maltex.....	4	250
Blueberry.....	0.5	89	Pettijohn's.....	2	380
Bouillon cube.....	27,000	1500	Wheatena.....	1	380
Brain, pig.....	150	340	Cheese, American Swiss	420	110
Brandy.....	3	4	Cheddar.....	540	130
Brazil nut.....	0.8	650	Cottage.....	320	80
Roasted in oil and salted.....	190	730	Cream.....	340	90

\* Edible portions only. Fresh, uncooked material unless otherwise described.

TABLE 385a—Continued

	Na, mg. per 100 Gm.	K, mg. per 100 Gm.	Food	Na, mg. per 100 Gm.	K, mg. per 100 Gm.
Food					
so, process.....	1500	440	Dextrin.....	14	14
ey (cheese food)....	1500	520	Dextrose.....	1	0.4
y, dark sweet.....	1	260	Dill, seed.....	12	1000
ned in sirup.....	0.7	77	Duck, domesticated,		
zen in sirup.....	1	280	breast meat.....	68	360
ht sweet, canned in			Leg meat.....	96	210
irup.....	3	55	Egg.....	140	130
nut.....	2	410	Whites only.....	200	140
en, breast meat.....	78	320	Yolks only.....	34	85
g meat.....	110	250	Eggplant.....	0.8	190
olate, milk.....	86	420	Endive.....	18	400
up.....	60	130	Farina.....	0.8	88
sweetened.....	4	830	Quick-cooking en-		
g, sweet (apple juice)....	4	100	riched.....	100	95
amon, ground.....	8	200	Fig.....	2	190
n, candied.....	290	70	Canned in sirup.....	1	110
.....	180	240	Dried.....	33	780
-Cola (soft drink).....	1	52	Filbert.....	0.8	560
a, powder, Dutch			Flour, bleached, enriched,		
process.....	55	3200	Gold Medal.....	1	86
inary, Hershey.....	4	1400	Phosphated.....	13	78
nut, dry, shredded.....	16	770	Buckwheat.....	1	680
.....	60	360	Gluten.....	2	24
rozen fillets.....	400	400	Rye, dark.....	1	860
liver oil.....	0.1	0	White, natural.....	1	120
salted.....	7200	80	Fruit cocktail, canned in		
pe, roasted.....	2	1600	sirup.....	9	160
flakes.....	660	160	Garlic.....	6	510
l meal, yellow, en-			Gelatin dessert, dry.....	330	210
riched.....	0.6	120	Plain, dry.....	27	11
l.....	0.2	0.1	Gin.....	0.7	0.3
opcorn, popped and			Ginger ale.....	8	0.6
oiled.....	3	320	Ground.....	29	1100
opped, oiled and			Gizzard, turkey.....	58	170
salted.....	1500	340	Gluten, wheat.....	2	24
arch.....	4	4	Gooseberry.....	0.6	87
weet white, canned....	200	200	Grape juice, Concord,		
Milk stage.....	0.2	240	sweetened, bottled.....	1	120
ellow, canned.....	210	200	Thompson Seedless.....	4	180
rozen.....	9	190	Grapefruit.....	0.4	200
Milk stage.....	0.3	370	Juice, sweetened,		
ellow, 5 varieties, dry....	0.4	290	canned.....	0.4	150
pea.....	1	560	Gravy flavoring.....	86	280
p, canned.....	1000	72	Halibut.....	56	540
ker, Graham.....	700	440	Ham, less excess fat....	2100	610
da.....	1500	500	Hash, corned beef,		
berry.....	1	65	canned.....	880	380
uce, canned.....	1	17	Heart, beef.....	90	160
m, whipping (32% fat).....	40	56	Turkey.....	69	240
umber, less parings....	0.8	230	Hominy, canned.....	180	50
ant.....	2	160	Honey.....	7	10
nte, dried (Zante			Horse-radish, prepared....	96	290
raisins).....	22	730	Ice cream, vanilla.....	100	90
y powder.....	45	1300	Jam, grape.....	7	78
delion.....	76	430	Kale.....	110	410
, semidry.....	0.9	790	Kidney, beef.....	210	310
			Lamb, less excess fat....	110	340

TABLE 385a—Continued

Food	Na, mg. per 100 Gm.	K, mg. per 100 Gm.	Food	Na, mg. per 100 Gm.	K, mg. per 100 Gm.
Lard . . . . .	0.3	0.2	Orange Juice, unsweetened, canned . . . . .	0.4	190
Lemon, less rind . . . . .	0.6	130	Oyster, fresh . . . . .	.73	110
Lettuce, head . . . . .	12	140	Pancreas, pig . . . . .	.57	240
Litchi, dried . . . . .	3	1100	Paprika, powder . . . . .	.82	2300
Liver, calf . . . . .	110	380	Parsley . . . . .	.28	880
Pig . . . . .	77	350	Parsnips . . . . .	.7	740
Turkey . . . . .	51	160	Pea . . . . .	0.9	380
Lobster, boiled in tap water . . . . .	210	180	Canned, less liquor . . . . .	230	180
Lonalac . . . . .	20	1200	Dry split . . . . .	.42	880
Reliquefied . . . . .	.2	160	Frozen . . . . .	100	160
Macaroni . . . . .	.1	160	Peach . . . . .	0.1	180
Mace, ground . . . . .	.45	180	Canned in sirup . . . . .	.6	31
Maize. See <i>Corn</i> .			Frozen in sirup . . . . .	.3	120
Maple sirup . . . . .	14	130	Peanut butter . . . . .	120	820
Marmalade, orange . . . . .	13	19	Oil . . . . .	0.2	0.1
Matzoth, American style . . . . .	360	130	Roasted in oil and salted . . . . .	460	700
Egg . . . . .	16	160	In shell . . . . .	0.8	740
Farfel . . . . .	28	130	Pear, Bartlett . . . . .	.2	100
Meal . . . . .	.4	125	Canned in sirup . . . . .	.8	52
Passover . . . . .	.1	140	Pecan . . . . .	0.2	420
Plain . . . . .	.1	140	Pepper, black, ground (spice) . . . . .	16	880
Poppy seed . . . . .	350	140	Green (vegetable) . . . . .	0.5	170
Tasty wafer . . . . .	430	260	Red, ground (spice) . . . . .	46	2400
Thin tea . . . . .	.2	130	White, ground (spice) . . . . .	.5	48
Whole wheat . . . . .	280	420	Persimmon, wild . . . . .	0.8	340
Mayonnaise . . . . .	600	17	Pickle, dill . . . . .	2300	330
Milk, buttermilk, cul- tured . . . . .	130	140	Pilchard. See <i>Sardine</i> .		
Dialyzed. Replaced by Lonalac . . . . .			Pineapple . . . . .	0.3	210
Evaporated . . . . .	100	270	Canned in sirup . . . . .	.1	120
Goat . . . . .	34	180	Frozen in sirup . . . . .	.1	38
Human, from 9 moth- ers, 3 to 10 days postpartum . . . . .	40	64	Juice, unsweetened, canned . . . . .	0.4	140
From 4 mothers, 49 to 77 days postpartum . . . . .	11	51	Plum . . . . .	0.1	140
Malted . . . . .	440	720	Canned . . . . .	.18	110
Whole, dry . . . . .	410	1100	Pomegranate, juice and pulp . . . . .	0.3	200
Liquid . . . . .	51	140	Popcorn, popped and oiled . . . . .	.3	320
Molasses, cane . . . . .	80	1500	Popped, oiled and salted . . . . .	1500	340
Mulberry . . . . .	0.6	200	Pork, less excess fat . . . . .	.58	260
Mushroom . . . . .	.5	520	Salt . . . . .	2900	260
Canned . . . . .	470	260	Postum (cereal bever- age), dry . . . . .	.36	1300
Mustard greens . . . . .	48	450	Instant, dry . . . . .	.71	2200
Powder . . . . .	.3	840	Potato chips . . . . .	.340	880
Prepared paste . . . . .	1100	280	Sweet, canned . . . . .	.48	200
Nutmeg, ground . . . . .	14	160	Less skin . . . . .	.4	530
Oats, rolled . . . . .	.2	340	White, canned . . . . .	.350	240
Okra, pods . . . . .	.1	220	Less skin . . . . .	0.6	410
Oleomargarine . . . . .	1200	230	Poultry seasoning . . . . .	.26	840
Olive, green pickled . . . . .	2200	290	Pretzel . . . . .	1100	330
Oil . . . . .	0.2	0.2	Prune, canned in sirup . . . . .	.3	220
Ripe pickled . . . . .	.920	240	Dried . . . . .	.5	600
Onion, white . . . . .	.1	130	Juice, unsweetened . . . . .	.2	260
Orange . . . . .	0.2	170			
Crush (soft drink) . . . . .	.2	100			

TABLE 385a—Continued

Food	Na, mg. per 100 Gm.	K, mg. per 100 Gm.	Food	Na, mg. per 100 Gm.	K, mg. per 100 Gm.
Skin.....	0.4	480	Spinach, Canned.....	300	260
Uned.....	2	240	Frozen.....	60	330
Breast meat.....	35	160	Squash, acorn.....	0.3	260
Meat.....	44	190	Hubbard.....	0.2	240
.....	0.6	290	Yellow summer.....	0.5	200
it, domesticated,			White summer.....	0.2	150
oreleg.....	47	370	Starch, corn.....	4	4
n.....	34	400	Strawberry.....	0.7	180
sh, with skin.....	8	260	Frozen, sweetened.....	2	180
n, seedless.....	21	720	Sugar, light brown.....	24	230
nte.....	22	730	White.....	0.3	0.5
berry, black.....	0.2	190	Tangerine.....	2	110
iental (wineberry).....	0.8	170	Juice, sweetened,		
d.....	0.4	130	canned.....	0.6	170
arb, stalks.....	1	70	Tapioca, granules.....	5	19
flakes.....	720	180	Tea, India-Ceylon-Java		
ffed.....	0.8	100	blend.....	4	1800
lashed and coated.....	2	130	Thyme, whole.....	36	500
aminized.....	4	170	Tobacco, chewing.....	1600	1800
.....	2	3	Tomato.....	3	230
.....	19	670	Canned.....	18	130
non.....	48	410	Juice, canned.....	230	230
anned.....	470	330	Tongue, beef.....	100	260
common. Theoreti-			Tripe, pickled.....	46	19
cal value for pure			Tuna, canned.....	540	480
NaCl.....	39,342	0	Turkey, breast meat.....	40	320
ine (herring), canned			Leg, meat.....	92	310
in oil.....	510	560	Turmeric.....	21	2700
ine (Pilchard), canned			Turnip, leaves.....	10	440
in natural sauce.....	760	260	White.....	37	230
tomato sauce.....	400	320	Yellow (rutabaga).....	5	260
erkraut, canned.....	730	490	Vanilla extract.....	1	74
age, Bologna.....	220	84	Veal, less excess fat.....	48	330
rankfurt.....	1100	330	Vinegar, cider.....	1	100
rk.....	1100	440	Distilled.....	0.6	15
tening, vegetable,			Walnut, black.....	2	460
Crisco.....	4	0	English.....	2	450
ry.....	0.4	0.2	Water, carbonated, I.....	18	0.6
mp.....	140	220	Carbonated, II.....	1	0.6
p, chocolate.....	60	130	Watermelon.....	0.3	110
apple.....	14	130	Wheat flakes.....	1000	540
orghum.....	20	600	Germ, containing some		
able (corn-and-cane).....	83	24	brand and flour.....	2	780
a, baking. Theoreti-			Gluten.....	2	24
cal value for pure			Puffed.....	3	340
NaHCO <sub>3</sub> .....	27,373	0	Shredded.....	2	340
hum sirup.....	20	600	Winter.....	2	430
b, beef, canned. Di-			Whisky, blended.....	0.3	1
luted as served.....	400	244	Bonded.....	0.1	0.6
tomato, canned. Di-			Wine, port.....	4	75
luted as served.....	400	440	Sauterne.....	10	87
vegetable, canned. Di-			Wineberry.....	0.8	170
luted as served.....	150	170	Worcestershire sauce.....	1400	360
ean, dry.....	4	1900	Yeast, compressed.....	4	360
our, solvent-			Debittered, dry.....	180	1900
extracted.....	0.6	1700	Primary cultured, dry.....	8-320	2000
hetti. See <i>Macaroni</i> .			Zwieback.....	250	170
ach.....	190	790			

TABLE 385b

SODIUM AND POTASSIUM CONTENT OF WATER SUPPLIES IN THE U. S.  
(Mead Johnson and Co.)<sup>42a</sup>

<i>Place</i>	<i>Na, mg. per 100 Cc.</i>	<i>K, mg. per 100 Cc.</i>	<i>Place</i>	<i>Na, mg. per 100 Cc.</i>	<i>K, mg. per 100 Cc.</i>
Aberdeen, S.D.....	20	2	Jackson, Miss.....	0.4	0.1
Albany, N.Y.....	0.2	0.2	Jacksonville, Fla.....	1	0.2
Albuquerque, N.M.....	5	0.7	Jefferson City, Mo.....	3	0.4
Annapolis, Md.....	0.2	0.2	Jersey City, N.J.....	0.3	0.2
Ann Arbor, Mich.....	2	0.5	Kansas City, Kan.....	4	0.4
Atlanta, Ga.....	0.2	0.2	Kansas City, Mo.....	10	3
Augusta, Maine.....	0.2	0.2	Lansing, Mich.....	1	0.2
Austin, Texas.....	3	0.5	Lincoln, Neb.....	3	0.7
Baltimore, Md.....	0.3	0.2	Little Rock, Ark.....	0.1	0.1
Bangor, Maine.....	0.2	0.1	Los Angeles, Calif.:		
Baton Rouge, La.....	9	0.2	Aqueduct source.....	6	0.6
Beloit, Wis.....	0.5	0.2	Metropolitan source... 17		0.6
Biloxi, Miss.....	23	0.6	River source.....	5	0.5
Birmingham, Ala.....	2	0.3	Louisville, Ky.....	2	0.3
Bismarck, N.D.....	6	0.6	Madison, Wis.....	0.4	0.2
Boise, Idaho.....	2	0.3	Manchester, N.H.....	0.2	0.1
Boston, Mass.....	0.3	0.2	Marion, Ohio.....	17	0.7
Brownsville, Texas.....	6	0.3	Memphis, Tenn.....	2	0.3
Buffalo, N.Y.....	0.7	0.3	Miami, Fla.....	2	0.3
Burlington, Vt.....	0.2	0.1	Milwaukee, Wis.....	0.3	0.1
Carson City, Nev.....	0.4	0.3	Minneapolis, Minn.....	0.5	0.3
Charleston, S.C.....	1	0.3	Minot, N.D.....	25	0.6
Charleston, W.Va.....	0.3	0.2	Montgomery, Ala.....	0.8	0.1
Charlotte, N.C.....	0.3	0.1	Montpelier, Vt.....	0.1	0.1
Charlottesville, Va.....	0.2	0.1	Nashville, Tenn.....	0.3	0.2
Cheyenne, Wyo.....	0.3	0.2	Nevada, Mo.....	33	0.7
Chicago, Ill.....	0.3	0.1	Newark, N.J.....	0.2	0.1
Cincinnati, Ohio.....	0.7	0.3	New Haven, Conn.....	0.3	0.1
Cleveland, Ohio.....	1	0.3	New Orleans, La.....	1	0.4
Columbia, S.C.....	0.4	0.2	New York, N.Y.....	0.3	0.2
Columbus, Ohio.....	5	0.6	Oakland, Calif.....	0.3	0.1
Concord, N.H.....	0.2	0.1	Oklahoma City, Okla.... 10		0.8
Crandall, Texas.....	170*	0.5	Olympia, Wash.....	0.5	0.3
Dallas, Texas.....	3	0.5	Omaha, Nebr.....	8	1
Denver, Colo.....	3	0.2	Philadelphia, Pa.....	2	0.4
Des Moines, Iowa.....	1	0.4	Phoenix, Ariz.....	11	0.7
Detroit, Mich.....	0.3	0.1	Pierre, S.D.....	9	0.5
Dover, Del.....	2	0.5	Pittsburgh, Pa.....	6	0.5
Durham, N.C.....	0.4	0.2	Portland, Maine.....	0.2	0.1
El Paso, Texas.....	7	0.6	Portland, Ore.....	0.1	0.1
Ephrata, Pa.....	0.3	0.2	Providence, R.I.....	0.2	0.1
Evansville, Ind.....	2	0.5	Raleigh, N.C.....	0.4	0.1
Fargo, N.D.....	5	0.7	Reno, Nev.....	0.5	0.1
Frankfort, Ky.....	0.3	0.1	Richmond, Va.....	0.7	0.2
Galesburg, Ill.....	30	2	Rochester, Minn.....	0.7	0.2
Galveston, Texas.....	34	0.7	Rochester, N.Y.....	0.3	0.2
Harrisburg, Pa.....	0.2	0.1	Sacramento, Calif.....	0.3	0.2
Hartford, Conn.....	0.2	0.1	Santa Fe, N.M.....	0.4	0.1
Helena, Mont.....	0.3	0.2	St. Louis, Mo.....	5	0.5
Houston, Texas.....	16	0.6	St. Paul, Minn.....	0.5	0.3
Huntington, W.Va.....	3	0.2	Salem, Ore.....	0.2	0.1
Indianapolis, Ind.....	1	0.3	Salt Lake City, Utah.....	0.8	0.2
Iowa City, Iowa.....	0.5	0.3	San Diego, Calif.....	5	0.5

\* An extreme example. This water is rarely drunk, but is used for cooking.

TABLE 385b—Continued

Place	Na, mg. per 100 Cc.	K, mg. per 100 Cc.	Place	Na, mg. per 100 Cc.	K, mg. per 100 Cc.
San Francisco, Calif.....	1	0.3	Topeka, Kan.....	1	0.5
Seattle, Wash.....	0.2	0.1	Trenton, N.J.....	0.1	0.1
San Diego, Calif.....	1	0.4	Tucson, Ariz.....	3	0.3
Springfield, Ill.....	0.8	0.3	Washington, D.C.....	0.3	0.3
St. Louis, Mo.....	0.2	0.1	Wichita, Kan.....	5	0.5
Tallahassee, Fla.....	0.3	0.1	Wilmington, Del.....	0.8	0.1

TABLE 386

CHOLESTEROL CONCENTRATION OF FOOD SAMPLES PURCHASED IN OPEN MARKET (EDIBLE PORTION)

(Okey, 1945)<sup>6</sup>.

Food	Moisture (Per Cent)	Fatty Acid (Per Cent)	Total Cholesterol (Per Cent Moist Weight)
Beef, round (medium fat).....	72.1	4.6	0.125
Lean.....	71.7	2.1	0.095
Beef shank.....	74.5	1.0	0.14
Breast.....	70.6	7.2	0.10
Pork spareribs.....	56.4	19.5	0.105
Poultry meats:			
Liver:			
Lamb (4 samples).....	67.1	5.9	0.61
Pork.....	69.6	3.7	0.42
Beef.....	68.0	3.7	0.32
Calf (4 samples).....	74.7	3.0	0.36
Chicken, ripe.....	82.7	4.1	0.15
Cornbread.....	79.1	1.0	0.28
Fish:			
Oysters, eastern.....	84.1	1.7	0.23
California I.....	87.6	2.9	0.28
California II.....	85.4	5.2	0.47
Crab.....	77.1	0.85	0.145
Cheeses:			
American.....	35.5	28.2	0.16
Processed.....	38.7	21.6	0.155
Swiss, processed.....	38.7	21.0	0.145
Monterey Jack.....	28.2	29.9	0.19
Cheddar.....	40.9	19.3	0.16
Hamburger, processed.....	51.3	20.0	0.135
Cheddar cream, processed.....	65.6	16.3	0.14
Butter.....	68.0	68.0	0.28
Egg yolk, dried.....	3.7	63.8	3.9
Fresh.....	49.5	33.1	2.0
Yeast.....	99.0	99.0	0.15
Wheat, raw.....			0.68
Wheat, yeast, dry.....			0.065

TABLE 387

CHOLESTEROL CONCENTRATION OF SUBSTANCES USED AS FOODS<sup>1</sup>

	"Fat" Per Cent Dry Weight)	Total Cho- lesterol Per Cent Dry Weight)	Moisture (Per Cent)	Fat (Per Cent Moist Weight)	Total Cholesterol Per Cent Moist Weight)
<b>Organs:</b>					
Beef brain.....	I, 49.4 II, 53.8	10.67 9.61	77.9 77.9	10.9 11.8	2.14 2.11
Beef heart.....	I, 17.4 II, 15.5	0.49 0.46	70.0 70.0	5.2 4.7	0.17 0.14
Beef kidney.....	I, 16.6 II, 17.9	1.60 1.67	74.9 74.9	4.2 4.5	0.44 0.41
Beef liver.....	I, 20.5 II, 25.5	0.86 0.63	69.7 69.7	6.2 7.7	0.29 0.19
Beef lung.....	I, 14.6 II, 15.0	1.95 1.75	80.0 80.0	2.9 3.0	0.39 0.35
Beef thymus (sweetbread)....	I, 10.5 II, 30.4	0.99 0.89	75.0 75.0	2.6 7.6	0.25 0.22
<b>Heart muscle:</b>					
Rabbit.....	.....	0.57	64.0	.....	0.20
"Av. mammal".....	.....	0.51	64.0	.....	0.18
Hen.....	.....	0.54	69.6	.....	0.16
Pigeon.....	.....	0.52	69.6	.....	0.16
Duck, wild.....	.....	0.52	69.6	.....	0.16
Turtle.....	.....	0.80	80.0	.....	0.16
<b>Skeletal muscle:</b>					
Beef.....	I, 14.2 II, 9.8	0.21 0.22	70.0 70.0	4.2 2.9	0.06 0.06
Lamb.....	11.2	0.24	71.0	3.2	0.07
Pork.....	22.4	0.175	64.0	8.0	0.06
Rabbit, laboratory.....	.....	0.17	67.9	.....	0.05
Wild.....	.....	0.25	67.9	.....	0.08
Veal.....	11.8	0.25	74.0	3.0	0.06
"Av. mammal".....	.....	0.27	67.9	.....	0.08
Chicken, light.....	12.7	0.35	73.0	3.4	0.09
Dark.....	7.0	0.32	72.5	1.9	0.06
"Hen".....	.....	0.25	73.0	.....	0.07
Duck.....	.....	0.21	68.8	.....	0.07
Pigeon.....	.....	0.41	74.0	.....	0.11
Codfish.....	9.5	0.29	82.6	1.6	0.05
Salmon.....	18.3	0.16	64.0	6.6	0.06
Shrimp.....	8.1	0.74	80.0	1.6	0.15
Turtle.....	I, 17.4 II	0.32 0.35	80.0 80.0	3.5 .....	0.06 0.07
<b>Eggs (hen's):</b>					
Frozen whole.....	.....	2.11	73.4	.....	0.56
Frozen yolk.....	.....	2.88	53.8	.....	1.33
Liquid, whole.....	.....	1.97	73.7	.....	0.518
Dehydrated, whole.....	.....	.....	.....	.....	2.14
Dehydrated, yolk.....	.....	.....	.....	.....	2.81
Fresh, whole.....	50.3	1.80	74.0	13.1	0.46

TABLE 388

PURINE CONCENTRATION OF FOODS PER 100 GM.\*

<i>Group I</i> (0-15 Mg.)	<i>Group II</i> (50-150 Mg.)	<i>Group III</i> (150-180 Mg.)
Vegetables	Meats	Sweetbreads
Fruits	Fish	Anchovies
Milk	Sea food	Sardines
Cheese	Beans, dry	Liver
Eggs	Peas, dry	Kidney
Cereals	Lentils	Meat extracts
	Spinach	

For individual analyses of the purine concentration of foods, see Turner.<sup>9</sup> Refer to Bridges Mattice<sup>8</sup> and/or Stern.<sup>7</sup>

TABLE 389

SE IN FOODS FROM GOITROUS AND NONGOITROUS REGIONS: PARTS PER BILLION OF DRY MATTER\*

(Sherman, 1946)<sup>1</sup>

<i>Kind of Food</i>	<i>Goitrous Regions</i>	<i>Nongoitrous Regions</i>
Wheat.....	1-6	4-9
Oats.....	10	23-175
Carrots.....	2	170
Carrots.....		507
Lettuce.....		618
Potatoes.....	85	226
Cabbage.....		776
Cranberries.....		26-35
Asparagus.....		946
Radishes.....		994
Tomatoes.....		379
Milk.....	265-322	572
Butter.....	140	
Sea foods:		
Cod fish.....		5350
Conch.....		1140
Crabmeat.....		1460
Flounder.....		1480
Oysters.....		1800-3500
Red snapper.....		1440
Salmon.....		570-2200
Shrimp.....		1100
Cod liver oil.....		7670
Cod liver oil.....		3000 13,000

\* For a more extensive list refer to Bridges and Mattice.<sup>2</sup>

AVERAGE SERVINGS OF COMMON FOODS ARRANGED FOR COMPARISON OF THEIR EXCESS OF ACID OR ALKALINE ASH IN TERMS OF NORMAL SOLUTION  
(Stern, 1944)<sup>8</sup>

<i>Excess of Acid or Alkaline Ash</i>	<i>More than 10 Grams</i>	<i>9.9 to 9.0 Grams</i>	<i>8.9 to 8.0 Grams</i>	<i>7.9 to 7.0 Grams</i>	<i>6.9 to 6.0 Grams</i>	<i>5.9 to 5.0 Grams</i>	<i>4.9 to 4.0 Grams</i>	<i>3.9 to 3.0 Grams</i>	<i>2.9 to 2.0 Grams</i>	<i>1.9 to 1.0 Gram</i>	<i>Less Than 1.0 Grams</i>
Acid Ash- Forming Foods	Cod, salt Ham, fresh lean Herring smoked Oysters	Beef, lean Chicken Fowl Liver, beef Pork, lean Salmon Veal, lean	Beef, fat Beef, m. fat Halibut Ham, smoked, lean Lamb Liver, calf Mackerel Mutton, lean Shad Veal, m. fat	Haddock Ham, smoked, m. fat Mutton, m. fat Pork, m fat Smelts	Ham, fresh, m. fat	Cod, fresh  Egg, whole		*Bacon *Sardines (C)			
							Miscellaneous				
							Egg, yolk		*Walnuts, English	Cheese, cheddar Corn, sweet Egg, white	Cocoanut, dried *Mayonnaise † Peanut butter Peanuts
							Breads and Cereals, Crackers				
								Barley Doughnut Oats, rolled Wheat, Cream of Shredded	Breads, all Farine Macaroni Noodles Rice, white Spaghetti	Cornflakes Cornmeal	**Cracker, gra- ham Saltine Soda †Flour, white **Sugar cookie

Alkaline Acid Forming Food	Beans, lima dried fresh Beef greens Beets Carrots Chard Fennel Spinach	Beans, lima (C)	Carrots (C) Rutabaga	Celery Cucumber Lettuce Potato white	Beans, baked (C) Potato, sweet	Beans, navy, string Cabbage Cauliflower Sauerkraut Tomatoes	Mushrooms	Beans, string (C) Pepper Radishes Squash Turnip	Dandelion greens Onions Peas dried fresh pumpkin	Asparagus Asparagus (C) Peas (C)
		12 4								
		14 4								
		27 6								
		10 8								
		10 9								
		13 6								
		11 8								
		27 6								



TABLE 391

CALCIUM AND OXALATE CONCENTRATION OF VARIOUS FOODS  
(Kohman, 1939)<sup>1</sup>

<i>Food Items</i>	<i>Total Solids (Per Cent)</i>	<i>Oxalic Acid (Per Cent)</i>	<i>Calcium (Per Cent)</i>
Vegetables:			
Asparagus.....	6.05	0.0052	0.0021
Beans, green pod (3).....	9.58	0.0310	0.044
Wax.....	7.80	0.041	0.004
Lima (2).....	24.25	0.0043	0.043
Beets, unpeeled.....	8.23	0.138	0.018
Beet leaves.....	6.60	0.916	0.120
Stems.....	6.66	0.338	0.040
Broccoli, leaves and flowers.....	10.50	0.0054	0.021
Stalks.....	7.57	0.0035	0.040
Cabbage (2).....	8.80	0.0077	0.188
Sprouts.....	8.52	0.0059	0.180
Chinese.....	6.45	0.0073	0.210
Carrots.....	11.02	0.033	0.044
Cauliflower.....	8.90	None	0.034
Celery stalks, bleached.....	4.58	0.034	0.054
Soup leaves.....	14.66	0.050	0.58
Soup stems.....	10.20	0.062	0.18
Collards (2).....	12.75	0.0091	0.061
Chard, Swiss, leaves.....	9.47	0.66	0.11
Stalks.....	7.10	0.29	0.045
Leaves and stalks (2).....	8.28	0.645	0.129
Chenopodium (Lamb's quarter).....	8.20	1.11	0.089
Corn, sweet, white.....	25.00	0.0014	0.0070
Yellow (2).....	33.51	0.0052	0.0032
Cress, land, wild.....	15.00	None	0.24
Early fine curled.....	8.80	0.0106	0.182
Cucumbers.....	3.72	None	0.014
Dandelions (3).....	11.38	0.0246	0.171
Eggplant.....	6.18	0.0069	0.010
Endive (5).....	7.58	0.0273	0.105
Escarole.....	6.10	0.0116	0.087
Kale.....	11.05	0.013	0.31
Minus leaf ribs.....	18.05	0.011	0.294
Lettuce (6).....	6.46	0.0071	0.073
Mustard greens (3).....	8.40	0.0077	0.221
Okra.....	13.20	0.048	0.077
Onions, green.....	13.65	0.023	0.057
Parsley.....	13.70	0.19	0.29
Parsnips.....	22.70	0.010	0.049
Peas.....	19.50	None	0.019
Peppers, sweet green (3).....	7.34	0.016	0.013
Poke.....	7.74	0.476	0.012
Potatoes, Irish.....	20.38	0.0057	0.0094
Sweet.....	33.60	0.056	0.014
Purslane, leaves.....	9.45	0.910	0.13
Stalks.....	8.44	0.518	0.067
Radishes.....	3.75	None	0.008
Rape.....	10.82	0.0015	0.11
Rhubarb.....	6.62	0.50	0.044

TABLE 391—Continued

<i>Food Items</i>	<i>Total Solids (Per Cent)</i>	<i>Oxalic Acid (Per Cent)</i>	<i>Calcium (Per Cent)</i>
<i>Apples—Continued</i>			
acid, 50) . . . . .	10.35	0.892	0.122
canned, 12) . . . . .	7.15	0.364	0.058
from New Zealand, leaves . . . . .	7.60	0.89	0.11
stake . . . . .	8.26	0.65	0.083
fresh, green summer . . . . .	5.51	None	0.036
skins, peeled . . . . .	8.16	None	0.037
unpeeled . . . . .	6.58	0.0018	0.028
chip greens . . . . .	8.25	0.0146	0.245
Apples, early summer . . . . .	12.58	None	0.010
Apples, early winter . . . . .	13.62	0.014	0.024
Apples, late . . . . .	14.60	None	0.0095
Apples, red . . . . .	23.81	0.0064	0.0071
Apples, black . . . . .	12.25	0.018	0.038
Apples, blue . . . . .	20.81	0.015	0.026
Black rasp . . . . .	22.10	0.053	0.058
Brambling . . . . .	13.70	0.014	0.027
Green goose . . . . .	13.05	0.088	0.023
Red rasp . . . . .	14.10	0.015	0.023
Raw . . . . .	10.48	0.019	0.031
Raspberries, red sour . . . . .	12.18	0.0011	0.010
Sweet, Bing . . . . .	24.50	None	0.0019
Raspberries, red . . . . .	15.52	0.019	0.030
Raspberries, Concord . . . . .	15.30	0.025	0.024
Raspberries, Thompson's seedless . . . . .	23.90	None	0.013
Raspberries, fruit . . . . .	11.50	None	0.015
Raspberries, juice . . . . .	9.20	None	0.011
Red . . . . .	18.90	0.083	0.17
Raspberries, juice . . . . .	10.39	None	0.015
Red . . . . .	31.00	0.11	0.26
Raspberries . . . . .	15.35	None	0.015
Raspberries, cantaloupe . . . . .	8.46	None	0.0090
Raspberries, Casaba . . . . .	11.22	None	0.0054
Raspberries, honey dew . . . . .	6.08	None	0.0090
Raspberries, Water . . . . .	10.42	None	0.0060
Raspberries, Starlines . . . . .	14.45	None	0.0084
Raspberries, edible portion . . . . .	15.15	0.024	0.038
Red . . . . .	22.90	0.078	0.15
Raspberries, Alberta . . . . .	15.68	0.0050	0.012
Raspberries, Wiley . . . . .	14.10	None	0.0089
Raspberries, Bartlett . . . . .	17.60	0.0030	0.014
Raspberries, Hawaiian, canned . . . . .	17.44	0.0062	0.019
Raspberries, damson . . . . .	11.70	0.010	0.015
Green gage . . . . .	13.20	None	0.0080
Raspberries, Italian . . . . .	15.76	0.0058	0.12
Raspberries, tomatoes . . . . .	5.76	0.0075	0.010

TABLE 392

## ORGANIC ACID CONSTITUENTS OF FOODS

(Bridges and Mattice, 1942)<sup>2</sup>

<i>Food Items</i>	<i>Citric Acid (Per Cent)</i>	<i>Malic Acid (Per Cent)</i>	<i>Other Acids</i>
Apples:			
Crab	0.03	1.02	
Delicious	None	0.27	
McIntosh	None	0.72	
Apricots, canned	1.06	0.33	
Dried	0.35	0.81	Trace of oxalic
Artichokes	0.10	0.17	Trace of tartaric
Asparagus	0.11	0.10	
Avocados	None	None	Trace of tartaric
Bananas	0.15	0.50	
Beans, lima	0.65	0.17	
String, green	0.03	0.13	
Blackberries	Trace	0.16	Traces of oxalic and cinic, 0.92% isocitric
Blueberries	1.56	0.10	Trace of oxalic
Brussels sprouts	0.24	0.20	
Cabbage	0.14	0.10	
Carrots	0.09	0.24	
Cauliflower	0.21	0.39	
Celery	0.01	0.17	
Cherries	0.01	1.25	Traces of oxalic, 0.06% succinic, 0.13% lactic
Clams, hardshell, meat	None		
Cocoa	0.53		
Cranberries	1.82	0.46	0.07% benzoic
Cranberries	1.10	0.26	Benzoic, 0.065%, quinic, 1% (Isham)
Currants	2.30	0.05	Traces of oxalic and cinic
Figs	0.34	Trace	
Gooseberry	Present	0.50 2.08	
Grapes		0.65	0.43% tartaric
Concord, juice	0.02	0.31	1.07% tartaric
Grapefruit	1.46		
Kale	0.35	0.05	
Lemons	3.84	Trace	
Juice	6.08	0.29	
Lettuce	0.02	0.17	
Loganberries	2.02	0.08	
Milk, whole	0.16		
Evaporated	0.36		
Powdered, whole	1.30		
Skimmed	1.32		
Okra	0.02	0.12	
Onions	0.02	0.17	
Oranges	0.98	Trace	
Florida	0.92	0.18	
Oysters, meat	0.03	0.18	
Parsnips	0.13	0.35	
Peaches	0.37	0.37	
Canned	0.05	0.69	

TABLE 392—Continued

<i>Food Items</i>	<i>Citric Acid (Per Cent)</i>	<i>Malic Acid (Per Cent)</i>	<i>Other Acids</i>
fresh.....	0.24	0.12	
ple.....	0.11	0.08	
.....	0.84	0.12	
.....	.....	0.36-2.39	
ornia.....	0.03	0.92	
ranate.....	4.52	None	
es, Idaho.....	0.51	None	
t (Cuban).....	0.07	None	
, Italian style.....	None	1.44	
.....	None	0.68-1.59	Trace of tartaric
berries, black.....	1.06		
k, canned.....	0.81	0.05	Trace of tartaric
.....	1.30	0.04	
anned.....	1.28	0.05	
rb.....	0.41	1.77	0.12% oxalic
h.....	0.08	0.09	
n.....	0.04	0.32	
berries.....	0.91, 1.08	0.10, 0.16	
ind.....	Trace	0.50	Traces of oxalic and suc- cinic, 7.76% tartaric
atoes.....	0.30, 0.47	0.05, 0.20	
os, white.....	None	0.23	

TABLE 393

## FOOD COMPOSITION TABLE FOR SHORT METHOD OF DIETARY ANALYSIS\*

(Turner, 1946)<sup>9</sup>

Food	Approximate Measure	Weight (Gm.)	Cal- ories	Pro- tein (Gm.)	Fat (Gm.)	Car- bohy- drate (Gm.)	Ca (Gm.)	P (Gm.)	Fe (Mg.)	Vita- min A (I.U.)	As- corbic Acid (Mg.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)
Cereal products: refined . . . . .	1 sl. bread (30 gm.); $\frac{1}{2}$ c. cooked cereal and cereal products (20 gm. dry); 1 c. prep. cereal (30 gm.); 3 soda crackers (20 gm.); 1 $\frac{1}{2}$ c. popcorn (20 gm.); 1 grid-dle cake. . . . .	80	2.5	1	15	0.01	0.03	0.2	0.02	0.02	0.2	0.2	0.6	0.6
Whole grain and enriched . . . . .	1 sl. bread (30 gm.); $\frac{1}{2}$ c. cooked cereal (20 gm. dry); 1 c. prep. cereal (30 gm.); 2 Graham crackers (20 gm.) . . . . .	80	2.5	1	15	0.01	0.04	0.6	0.06	0.04	0.6	0.6	0.6	0.6
Dairy products: butter. . . . .	1 tsp. . . . .	5	35	4	10	0.25	0.18	0.3	0.01	0.14	0.3	0.01	0.14	0.3
Cheese, Cheddar type. . . . .	1 cu. in. . . . .	30	120	7.0	10	4	0.08	0.26	0.2	70	0.01	0.01	0.13	0.2
Cheese, cottage, skim . . . . .	$\frac{1}{2}$ c. . . . .	100	100	19.0	1	1	0.03	0.02	0.1	360	0.01	0.01	0.04	0.1
Cream, light. . . . .	$\frac{1}{2}$ c. . . . .	130	150	7.0	7	15	0.13	0.14	0.9	435	0.08	0.08	0.26	0.1
Custard . . . . .	$\frac{1}{2}$ c. . . . .	50	80	6.5	6	16	0.03	0.10	1.4	495	0.07	0.07	0.18	0.1
Eggs . . . . .	1 med. . . . .	80	165	3.0	10	12	0.06	0.05	0.1†	265	0.02	0.02	0.21	0.1
Ice cream, commercial . . . . .	$\frac{1}{2}$ c. . . . .	240	90	8.5	1	12	0.29	0.23	0.2†	25	2	0.11	0.43	0.2
Milk, buttermilk, skim. . . . .	1 c. . . . .	240	160	8.5	9	12	0.28	0.22	0.2†	410	2	0.10	0.43	0.3
Milk, whole . . . . .	1 c. . . . .	240	160	8.5	9	12	0.28	0.22	0.2†	410	2	0.10	0.43	0.3
Desserts: cake, plain, chocolate . . . . .	1 piece cake $2\frac{1}{2} \times 2\frac{1}{2} \times 2\frac{1}{2}$ in. (75 gm.), for iced add 1 serving sweets; 1 waffle 6 in. dia. (60 gm.) . . . . .	225	4.0	11	28	0.03	0.06	0.8	0.09	0.11	0.6	0.09	0.11	0.6
Cookies, plain . . . . .	2 med. 3 in. dia.; 1 brownie . . . . .	40	150	2.0	7	20	0.01	0.03	0.3	155	0.04	0.04	0.03	0.2
Pudding . . . . .	$\frac{1}{2}$ shell, single crust . . . . .	25	105	1.5	6	11	0.02	0.02	0.4	230	0.06	0.06	0.04	0.5
Pudding, cream filling . . . . .	$\frac{1}{2}$ c. . . . .	140	210	4.5	6	35	0.16	0.13	0.6	230	0.06	0.06	0.04	0.1

Fats.....	2 sl. bacon (20 gm.); 1 tbsp. fat (12 gm.); 1 tbsp. mayonnaise (15 gm.); 1 cu. in. salt pork (15 gm.); 1½ tbsp. French dressing (15 gm.)	120 50	1.0 12.5	13	..... .....	0.01 0.14	0.2 1.5	5 .....	0.01 0.05	0.01 0.06	0.2 0.8
Fish: cod, halibut, fresh, cooked	1 med. serving	75			.....						
Halibut, herring, tuna, white-fish, cooked.....	1 med. serving; tuna (60 gm.); others (75 gm.)			5	.....		0.8	35	0.04	0.08	2.4
Salmon, canned	1 med. serving	75		7	.....		0.7	220	0.02	0.12	5.9
Fruits: banana	1 small	100			23	0.01	0.6	350	0.04	0.07	0.6
Cantaloupe	½ melon, 4½ in. dia.	150			8	0.02	0.6	3600	0.08	0.08	0.1
Citrus.....	1 med. orange; ½ med. grapefruit; ½ c. juice; 1 med. large lemon.	100			11	0.02	0.4	180	0.07	0.03	0.2
Yellow, fresh, canned, dried..	Fresh (100 gm.): 1 med. peach, 2 to 3 apricots, 3 plums; dried (30 gm.), add ½ serving sweets; for sweetened canned, dried or fresh, add 1 serving sweets.		.5		13	0.01	0.4	585	0.01	0.02	0.6
Other, dried.....	3 to 4 dates; 1½ to 2 small figs; dried apple; ½ c. raisins	30	.5		22	0.02	0.9	30	0.04	0.03	0.2
Other, fresh and canned.	½ c. cooked; sweetened, add 1 serving sweets				15	0.01	0.4	80	0.02	0.02	0.1
Gravy: white sauce	½ c. ....	60	2.5	5	4	0.05	0.2	180	0.04	0.11	0.1
Legumes: beans, peas	½ c. cooked; dried (30 gm.)	105	6.5		19	0.03	2.4	20	0.14	0.06	0.5
Soybeans	½ c. cooked; dried (30 gm.)	105	10.5	5	4	0.07	2.5	55	0.24	0.10	0.8
Meat: beef, fowl, lamb, veal, cooked	1 med. serving	75	18.0	10		0.01	3.1	20	0.09	0.15	3.9
Liver, cooked	1 small serving	60	12.0	2	4	0.01	4.9	16,500	0.12	1.22	6.0
Luncheon meats, cooked.....	2 sl. sausage, minced ham, dried beef, luncheon roll (30 gm.); ½ frankfurter (30 gm.)	80	5.0	6	1	.....	0.7		0.09	0.07	0.8

\* The nutritive value of food mixtures such as macaroni and cheese, Spanish rice, chow mein, creamed vegetables, soups, etc., should be computed on the basis of the kind and approximate amount of the foods in the combination.

+ Revised to correspond with recent values in Misc. Pub. No. 572, U.S. Department of Agriculture (1945).

TABLE 393—Continued

Food	Approximate Measure	Weight (Gm.)	Cal- ories	Pro- tein (Gm.)	Fat (Gm.)	Car- bohy- drate (Gm.)	Ca (Gm.)	P (Gm.)	Fe (Mg.)	Vita- min A (I.U.)	As- corbic Acid (Mg.)	Thia- mine (Mg.)	Ribo- flavin (Mg.)	Nia- cin (Mg.)
Meats—Continued														
Pork; ham, cooked	1 med. serving	75	205	18.0	15		0.01	0.18	2.4			0.60	0.15	3.2
Nuts	1 tbsp. peanut butter; 8 to 15 halves walnuts; 16 peanuts; 12 to 15 almonds; 12 halves pecans	15	95	3.5	8	3	0.01	0.06	0.3			0.03	0.02	1.4
Sweets: candy, sugar, syrup	1 tbsp. sugar, jelly, jam, syrup, honey; 1 serving plain Jello; plain candy (fondant or mints, 14 gm.); 6-oz. bottle soft drink		55			14								
	1 2-oz. chocolate-coated bar	20	275	5.0	13	35	0.05	0.10	1.4			0.03	0.09	3.3
Candy bar	1 tbsp.		50			12	0.04	0.01	1.3			0.01	0.04	
Molasses; sorghum														
Vegetables: cabbage; sauerkraut, cooked		100	25	1.5		5	0.05	0.03	0.5	30	28†	0.05	0.04	0.2
Cabbage, raw; cauliflower, cooked														
Corn; parsnips, cooked	1 c. cabbage (50 gm.); $\frac{2}{3}$ c. cauliflower (70 gm.)		15	1.0		3	0.02	0.02	0.3	20	26	0.04	0.03	0.1
(Green and yellow; asparagus, cooked)	$\frac{1}{2}$ c. corn; 1 large parsnip.	100	95	2.0	1	20	0.02	0.07	0.4	75	6	0.04	0.05	0.6
Broccoli, cooked		100	25	2.0		4	0.02	0.04	0.9	775	38§	0.14§	0.11	1.0
Carrots, cooked		100	35	3.5		6	0.15	0.08	1.4	4800	63	0.08	0.28	0.6
Green beans, cooked		100	40	1.0		9	0.04	0.04	0.8	12,000	3	0.04	0.06	0.5
Leafy green, cooked		100	40	2.5		8	0.06	0.04	1.4	480	13§	0.06§	0.12	0.4
	$\frac{1}{2}$ c. kale, spinach, turnip, other greens	100	30	2.5		4	0.25	0.05	2.7	6385	46§	0.08§	0.27	0.5
Peas, fresh, cooked, canned	$\frac{1}{2}$ c.	100	70	4.5		12	0.02	0.09	1.4	590	11§	0.15§	0.09	1.1
Sweet potato, cooked	1 large	100	130	2.0	1	28	0.04	0.05	0.7	5920	14	0.08	0.06	0.5
Potato, cooked	1 small; for fried add 1 serving fats	100	85	2.0		19	0.01	0.05	0.7	35	8	0.08	0.03	1.0

TABLE 393—Continued

TABLE 55.—Continued												
Vegetables—Continued												
Tomato, fresh, canned, juice.	1 c.; 1 small tomato (100 gm.); 2 1/2 tbsp. catsup (50 gm.) add 1/2 serving sweets	20	1.0	4	0.01	0.02	0.6	990	19	0.05	0.03	0.7
Other, cooked	100 1 c. beets, eggplant, onions, rutabagas, etc.	45	1.5	10	0.04	0.04	0.6		8	0.01	0.02	0.2
Other, commonly served raw.	2 pieces celery; 8 sl. cucumber; 1/2 hd. lettuce	10	0.5	2	0.02	0.01	0.2	70	3	0.03	0.02	0.1

+ For sauerkraut, omit ascorbic acid.

† For sauerkraut, 0.010 g ascorbic acid. ‡ For canned reduce ascorbic acid and thiamine by one half.

|| Calcium unavailable in chard, spinach, and beet greens.

TABLE 394

## VITAMIN SUMMARY

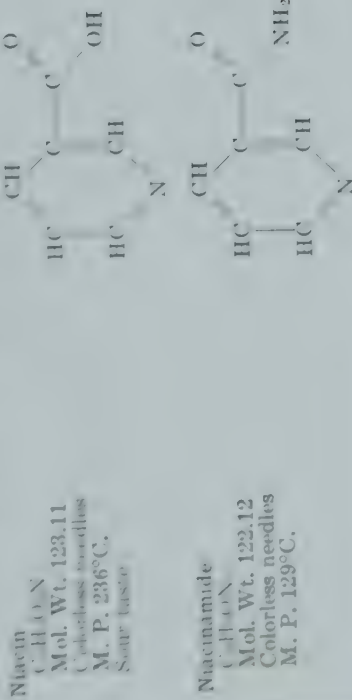
(Quaker Oats Company, 1948)<sup>16</sup>

## THE VITAMIN B COMPLEX

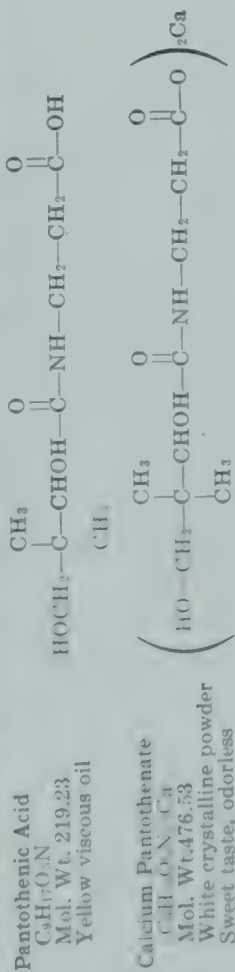
## Water-Soluble Vitamins

NAMES, FORMULAS AND CHEMICAL PROPERTIES	UNITS, ASSAY METHODS, BIOLOGICAL FUNCTIONS AND SOURCES
<p><b>THIAMINE</b>, Vitamin B<sub>1</sub>, or the antineuritic vitamin, occurs naturally as the free compounds or its salts, as a thiamine-protein complex, or as thiamine pyrophosphate (cocarboxylase). Thiamine is soluble in water and alcohols, insoluble in lipid solvents, stable to heat in strong acid solutions, unstable in neutral or alkaline solution, sensitive to oxidation and reduction and undergoes cleavage when treated with bisulfite, barium nitrite or sodium acetate solutions.</p> <div> </div> <p>Thiamine Hydrochloride  <math>C_{12}H_{16}ON_4SCl_2</math>  Mol. Wt. 337.26  Colorless monoclinic  needles M. P. 248-250°C.  Nutlike odor</p>	<p><b>Units:</b> 1 USP unit or IU is the activity possessed by 3.0 micrograms of pure crystalline thiamine hydrochloride.</p> <p><b>Standard:</b> USP reference standard Thiamine Hydrochloride.</p> <p><b>Assay Methods:</b> The thiochrome method is official for drugs and is tentative AOAC method for foods. Rat polymyositis curative method is the official biological method when thiochrome is not applicable. Other methods include rat growth, yeast fermentation and colorimetric methods.</p> <p><b>Biological Functions:</b> Thiamine is essential for growth and the prevention of beriberi. Cocarboxylase is active in decarboxylation of pyruvic acid and is therefore important in normal carbohydrate metabolism. Deficiency symptoms which may respond to thiamine therapy are emotional hypersensitivity, loss of appetite, constipation, susceptibility to fatigue, muscular weakness and atrophy, and polyneuritis.</p> <p><b>Sources:</b> Enriched cereals, whole grain cereals, milk, legumes, meats. Special sources include yeast, concentrates and synthetic thiamine.</p>
<p><b>RIBOFLAVIN</b>, Vitamin B<sub>2</sub>, or Vitamin G, occurs naturally in the free form or in various chemical complexes with protein, phosphoric acid, adenine or nucleic acid. The pure compound is only slightly soluble in water and alcohols, insoluble in lipid solvents, stable to heat in dry form and in acid solution, stable to ordinary oxidation, unstable in alkaline solution and sensitive to light. In solution, riboflavin has an intense greenish yellow fluorescence.</p> <div> </div> <p>Riboflavin  <math>C_{17}H_{20}N_4O_6</math>  Mol. Wt. 376.36  Orange yellow crystals  M. P. 282°C.  Bitter taste</p>	<p><b>Units:</b> Amounts are expressed in milligrams or micrograms of riboflavin.</p> <p><b>Standard:</b> USP reference standard Crystalline Riboflavin.</p> <p><b>Assay Methods:</b> Microbiological method is official for drugs and tentative AOAC method for foods. Other methods include the fluorometric and rat growth methods.</p> <p><b>Biological Functions:</b> Riboflavin is essential for growth. A riboflavinosis in man may be characterized by cheilosis, angular stomatitis, glossitis, seborrheic dermatitis and eye disorders such as itching and burning sensations, mild photophobia and vascularization of the cornea. These signs and symptoms are not, however, restricted to deficiency diseases, and among deficiency diseases not all are restricted to riboflavinosis.</p> <p>Riboflavin is a constituent of several enzyme systems in animal tissue which are important in carbohydrate and amino acid metabolism.</p> <p><b>Sources:</b> Milk, evaporated milk, green leafy vegetables, egg yolk, liver, kidney and other meats, enriched flour and bread. Special sources include yeast, miscellaneous concentrates and synthetic riboflavin.</p>

niacinamide, nicotinic acid, and nicotinic anhydride. Niacin is soluble in water and alcohol, but insoluble in most lipid solvents, stable to heat and oxidation.



**PANTOTHENIC ACID**, the chick antidermatitis factor, occurs in nature as the free acid and is usually marketed as the calcium salt. Pantothenic acid is soluble in water and other organic solvents, insoluble in benzene and chloroform, decomposes towards acids, bases and heat. The calcium salt is soluble in water and more stable to heat than the free acid, unstable to acid, alkali, ferric salts and calcium precipitants.



**BIOTIN**, Vitamin H, the yeast growth or anti-egg-white-injury factor, is an organic acid. Several derivatives, including the oxygen analogue, have biological activity for at least some species. The methyl ester of biotin has been prepared and is active for animals, but not for all micro-organisms. Biotin is soluble in water and alcohol, insoluble in petroleum ether, ether, chloroform, stable to heat, acid and alkali.



Standard: USP reference standard Crystalline Nicotinic Acid.

**Assay Methods:** The microbiological method is official for drugs and tentative AOAC method for foods. Other methods include the colorimetric cyanogen bromide-amine method, black-tongue curative and chick growth methods.

**Biological Functions:** Niacin is essential to many animals for growth and health. The rat, and perhaps other animals, is able to dispense with an external supply of niacin if supplied, with adequate amounts of the indispensable amino acid, tryptophane. In man, niacin is believed necessary along with other vitamins of the B complex for the prevention and cure of pellagra. Niacin is a constituent of enzyme systems which take part in protein and carbohydrate metabolism by transporting hydrogen.

**Sources:** Meat, fish, milk, enriched cereals, whole grains. Special sources include yeasts, miscellaneous concentrates and synthetic niacin.

**Units:** Amounts are usually expressed as milligrams or micrograms of pantothenic acid.

Standard: USP reference standard Crystalline Calcium Pantothenate.

**Assay Methods:** Microbiological method using *Lactobacillus casei* or *arabidopsis*. Other methods include chick growth and yeast growth tests.

**Biological Functions:** Although pantothenic acid is found in most living tissue, its exact role is not known. It prevents dermatitis in chicks, graying hair and hemorrhagic adrenal glands in young rats. In dogs, deficiency results in hypoglycemia, convulsions, fatty liver and gastrointestinal disturbances. It is necessary for growth in chicks, rats and micro-organisms. There is some evidence that pantothenic acid is present in a coenzyme concerned with biological acylations and important in the metabolism of fat and carbohydrate.

**Sources:** Widely distributed in foods: liver and kidney, yeast, crude molasses, milk, bran and whole grain cereals. Special sources include rice bran extract and preparations containing calcium pantothenate.

**Units:** Amounts are expressed in milligrams or micrograms of biotin. One vitamin H unit is the daily amount necessary to cure egg white injury in rats. One mg. of biotin methyl ester equals 27,000 Vitamin H units.

**Assay Methods:** Microbiological methods using *L. lactobacillus* or other organisms have supplanted the rat curative assay.

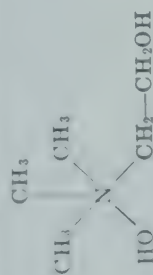
**Biological Functions:** Biotin is necessary for the maintenance of health in animals and for growth of many micro-organisms. Deficiency in experimental animals results in dermatitis, loss of hair, and abnormal gait. Deficiency in humans is difficult to produce, but has been reported as characterized by seborrheic dermatitis, pallor of skin, mental depression and muscular pains. Avidin, a raw egg protein, induces biotin deficiency by forming a nonabsorbable biotin-avidin complex. It has been suggested that biotin is in some manner concerned with fixation of carbon dioxide in the metabolism of pyruvic acid.

**Sources:** Egg yolk, kidney, liver, yeast, milk, molasses. Special sources include synthetic biotin or its methyl ester.

TABLE 394—Continued  
THE VITAMIN B COMPLEX (Continued)

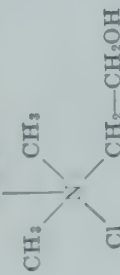
NAMES, FORMULAS AND CHEMICAL PROPERTIES	UNITS, ASSAY METHODS, BIOLOGICAL FUNCTIONS AND SOURCES
<p><b>VITAMIN B<sub>6</sub></b>, the antiacrodynia vitamin, occurs in at least three forms, pyridoxine, pyridoxal and pyridoxamine. All three of these forms are about equally active for rats, but not for certain micro-organisms. For some time pyridoxine was the only known compound with Vitamin B<sub>6</sub> activity. Pyridoxine is soluble in water, alcohol and acetone, slightly soluble in other organic solvents, stable to heat, concentrated acid and alkali, but is destroyed by light. It is marketed as the hydrochloride, but can be obtained as the free base.</p>	<p><b>Units:</b> Amounts are expressed in milligrams or micrograms of pyridoxine.</p> <p><b>Standard:</b> USP reference standard Crystalline Pyridoxine Hydrochloride.</p>
<p><b>Pyridoxine Hydrochloride</b> C<sub>8</sub>H<sub>11</sub>O<sub>3</sub>NC1 Mol. Wt. 205.64 Colorless crystals M. P. 204-205°C. Salty taste, odorless</p>	<p><b>Assay Methods:</b> Microbiological method, using <i>S. carlsbergensis</i> or <i>Neurospora</i>. Other methods include rat growth and acrodynia cure test.</p>
<p><b>Pyridoxal</b> C<sub>8</sub>H<sub>9</sub>O<sub>3</sub>N Mol. Wt. 167.16</p>	<p><b>Biological Functions:</b> Pyridoxine appears to be related to the metabolism of fats and amino acids. There is evidence that phosphorylated pyridoxal is the coenzyme for several bacterial decarboxylases and transaminases. Rats deprived of pyridoxine develop a symmetrical dermatitis (acrodynia), muscular weakness, convulsions, and fail to grow. There is no definite knowledge of the signs and symptoms of pyridoxine deficiency in man. In dogs and other animals a deficiency of this vitamin may result in anemia, degeneration of skeletal and cardiac musculature, and degeneration of the nervous tissue of the spinal cord. Pyridoxine, with others of the B vitamins, may be helpful in the treatment of pellagra.</p>
<p><b>Pyridoxamine</b> C<sub>8</sub>H<sub>12</sub>O<sub>3</sub>N<sub>2</sub> Mol. Wt. 168.19</p>	<p><b>Sources:</b> Vegetable fats, whole grain cereals, legumes, yeast, meats and fish. Synthetic pyridoxine, pyridoxal, and pyridoxamine are available.</p>
<p><b>FOLIC ACID:</b> Pteroylglutamic acid (PGA) has been shown to be one of the most active of the naturally occurring interrelated factors previously referred to as <i>L. casei</i> factor(s), SLR factor, Vitamin M, norite eluate factor, Vitamin B<sub>9</sub> and B<sub>9</sub> conjugate, and folic acid. It has been proved identical with "Liver <i>L. casei</i> factor" obtained by isolation. The "fermentation form" and "yeast form" of folic acid differ from PGA by containing additional glutamic acid units. The free acid is slightly soluble in water. The sodium salt is freely soluble in water. Both are insoluble in lipid solvents. Stable to heat in neutral and alkaline solution. Destroyed by heating with acid. Inactivated by light.</p>	<p><b>Units:</b> Amounts are expressed in micrograms of folic acid.</p> <p><b>Assay Methods:</b> Microbiological method, using <i>L. casei</i> or <i>S. faecalis</i>. Antianemia potency has been estimated, using rats, chicks, monkeys.</p>
<p><b>Pteroylglutamic Acid</b> C<sub>20</sub>H<sub>17</sub>N<sub>7</sub>O<sub>6</sub> Mol. Wt. 441.21 Orange yellow needles or platelets Tasteless, odorless</p>	<p><b>Biological Functions:</b> PGA or simple derivatives are required by several micro-organisms for growth. Deficiency in higher animals results in retardation of growth, anemia and leukopenia, achromatrichia in the rats, poor feathering in chick, and diarrhea and edema in the monkey. It has been shown clinically that synthetic PGA is effective in the treatment of tropical sprue, pernicious (Addisonian) anemia, and nutritional macrocytic anemias associated with pregnancy, pellagra, and the administration of sulfa drugs. In the case of pernicious anemia, folic acid administration restores the normal blood picture but does not arrest the nervous tissue degeneration. The biochemical mechanism of action is unknown.</p>
<p>HOOC-CH-CH<sub>2</sub>-CH<sub>2</sub>-COOH</p>	<p><b>Sources:</b> Green plant tissue, liver, yeast, synthetic pteroylglutamic acid.</p>

**CHOLINE**, an antifatly liver factor, is a strong organic base, occurring in nature as a component of certain phospholipids or as acetylcholine. It is marketed as choline chloride. Choline and choline chloride are soluble in water and alcohol, insoluble in ether, petroleum ether, benzene and carbon disulfide, stable to heat in acid solution, unstable in alkaline solution, extremely hygroscopic.



**Choline**

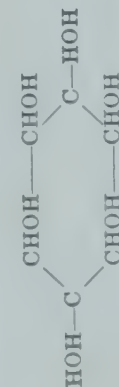
$\text{C}_5\text{H}_{12}\text{O}_2\text{N}$   
Mol. Wt. 121.13  
White crystals  
M. P. decomp.  
Causative bitter taste



**Choline Chloride**

$\text{C}_5\text{H}_{11}\text{ONCl}$   
Mol. Wt. 139.63  
White crystals  
Salty bitter taste

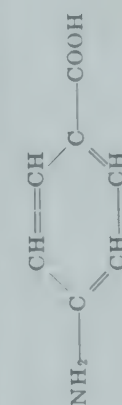
**INOSITOL**, which may be an antialopia factor, occurs in the free form and in various complexes, such as phytin and inositol. Inositol is soluble in water, insoluble in absolute alcohol and petroleum ether, stable to heat, strong acid and alkali.



**Inositol**

$\text{C}_6\text{H}_{12}\text{O}_6$   
Mol. Wt. 180.16  
White crystals  
M. P. 225-226°C.  
Sweet taste

**PARA-AMINOBENZOIC ACID**, one of the antigray-hair factors, occurs in nature in association with other members of the B complex, in the free state, acetylated and conjugated with peptide. It is soluble in alcohol and boiling water, stable in acid and alkaline solution, unstable to ferric salts and strong oxidizing agents.



**Para-aminobenzoic acid**

$\text{C}_7\text{H}_7\text{O}_2\text{N}$   
Mol. Wt. 137.13  
Colorless crystals  
M. P. 186-187°C

**Units:** Amounts are expressed in milligrams of choline.

**Standard:** USP reference standard Choline Chloride.

**Assay Methods:** The USP method based on the colorimetric comparison of choline reductase in acetone is official for drugs. The microbiological method, using *Neurospora*, is supplanting chemical and biological assays for choline in natural materials.

**Biological Functions:** Choline acts as a dietary factor important in furnishing free methyl groups for transmethylation. Acetylcholine performs an important function in the animal body as a mediator of nerve impulses. A deficiency of choline leads to fatty livers in rats and other animals, to hemorrhagic kidney damage in young rats, perosis in chicks, cirrhosis of liver in rats, rabbits and dogs. It is a growth factor for rats and chicks. May be useful in the treatment of cirrhosis of the liver in man.

**Sources:** Egg yolk, kidney, liver, heart, seeds, cereal grains and germ, vegetables and legumes. Other compounds, methionine, betaine, arsenocholine, have some of the biological properties of choline.

**Units:** Amounts are expressed in milligrams of inositol.

**Assay Methods:** The microbiological method, using *S. cerevisiae* or *Neurospora sitophila*, has been used in favor of chemical and biological methods.

**Biological Functions:** The nutritional status of inositol is controversial. Under certain conditions inositol appears to prevent alopecia, promote growth, have lipotropic activity and influence gastrointestinal motility. Conflicting observations indicate that inositol is not a dietary essential or that it may be involved in intestinal flora activity.

**Sources:** Fruits, especially citrus, cereal grains, liver, kidney, heart and other meats.

**Units:** Amounts are expressed in milligrams of para-aminobenzoic acid.

**Assay Methods:** May be determined by colorimetric chemical methods or by microbiological methods.

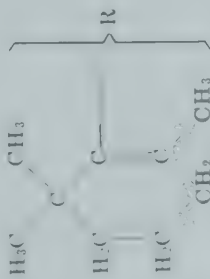
**Biological Functions:** Required by many organisms for growth, active in neutralizing the antibacteriostatic effect of some sulfonamide drugs, inhibits rickettsial organisms and has been used in treatment of typhus fever. Removal from diet may cause achromotrichia in rats and failure of growth in chicks. Para-aminobenzoic acid occurs in folic acid in chemical combination with glutamic acid and a pteridine.

**Sources:** It is widely distributed in nature. Yeast is apparently the best source. The synthetic product is available in special drug preparations.

TABLE 394—Continued  
OTHER WATER SOLUBLE VITAMINS

NAMES, FORMULAS AND CHEMICAL PROPERTIES	UNITS, ASSAY METHODS, BIOLOGICAL FUNCTIONS AND SOURCES
<p><b>ASCORBIC ACID</b>, Vitamin C, the antiscorbutic vitamin, is found naturally in two biologically active forms, the reduced and the oxidized form. Both compounds are soluble in water, insoluble in organic solvents, unstable to oxidation, light and alkali and certain metals.</p> <p><b>1—Ascorbic acid (reduced form)</b>  <math>C_6H_8O_6</math>  Mol. Wt. 176.12  White crystals  M. P. 190-192°C.  Sour taste</p> $  \begin{array}{c}  \text{H} & \text{H} & & \text{O} \\    &   & &   \\  \text{HO}-\text{C} & -\text{C}- & \text{C}- & \text{C}-\text{C}=\text{O} \\    &   &   &   \\  \text{H} & \text{O} & \text{H} & \text{O} \\    &   &   &   \\  \text{H} & \text{H} & \text{H} & \text{H}  \end{array}  $	<p>Units: Amounts are expressed in milligrams of ascorbic acid; 1 IU is the activity of 0.05 mg. of ascorbic acid.</p> <p>Standard: USP reference standard Crystalline Ascorbic Acid.</p> <p>Assay Methods: Titration with 2,6-dichlorophenolindophenol is the official method for drugs and foods.</p> <p>Biological Functions: Vitamin C is essential for the formation of intercellular substances of the teeth and bones. It prevents and cures scurvy, increases resistance to infection, promotes firm gums in vitamin C-deficient persons. It may be an important factor in cellular oxidation and reduction processes, and may be required for the normal, complete metabolism of aromatic amino acids.</p> <p>Sources: Oranges and other citrus fruits, tomatoes, potatoes, green leafy vegetables, other fruits and commercially canned fruits and vegetables. Special sources include preparations containing concentrates and synthetic ascorbic acid.</p>
<p><b>Dehydro-ascorbic acid (oxidized form)</b>  <math>C_6H_6O_6</math>  Mol. Wt. 174.11</p> $  \begin{array}{c}  \text{H} & \text{H} & & \text{O} \\    &   & &   \\  \text{HO}-\text{C} & -\text{C}- & \text{C}- & \text{C}-\text{C}=\text{O} \\    &   &   &   \\  \text{H} & \text{O} & \text{H} & \text{O} \\    &   &   &   \\  \text{H} & \text{H} & \text{H} & \text{H}  \end{array}  $	<p>Assay Methods: No completely satisfactory method for estimating vitamin P has been developed. Tentative methods are based upon the measurement of capillary fragility in test animals. Various fruit extracts have been used for provisional standards.</p> <p>Biological Functions: Vitamin P restores fragile and permeable capillaries to a normal state. It appears to be beneficial in the treatment of certain hemorrhagic conditions in man, but its role as a dietary essential has not been established.</p> <p>Sources: Citrus fruits, rose hips, black currants.</p>
<p><b>VITAMIN P</b> and Citrin are terms used to designate a dietary factor, independent of vitamin C, necessary for maintenance of normal capillary strength. The isolation of a chemical entity which can be identified as vitamin P has not been accomplished. Several flavones, hesperidine, rutin, methyl chalcone, as well as concentrates from lemons and other citrus fruits, have vitamin P activity.</p>	

**VITAMIN A**, the antixerophthalmic vitamin, occurs in three or more forms. Crystalline A vitamins are pale yellow to yellow, soluble in fats, insoluble in water, oxidize readily, but are stable to alkali, acid and to heat in the absence of oxygen. Vitamin A is found in animal tissues as the free alcohol or in the ester form. No free or esterified vitamin A is found in plant tissue, but certain carotenoids, which are precursors of Vitamin A, are found. Beta-carotene is the most active of nine other carotenoids known to have vitamin A activity, since both its rings are of the beta-ionone type.



Ring fragment of beta-ionone

**Beta-carotene**,  $\text{C}_{40}\text{H}_{56}$   
Mol. Wt. 536.85  
Red crystals  
M. P. 187°C.  
Abs. Max. 454 mu



**Vitamin A<sub>1</sub>**,  $\text{C}_{20}\text{H}_{30}\text{O}$   
Gadol (from Cod Liver Oil)  
Mol. Wt. 286.44  
Yellow prisms  
M. P. 62-64°C.  
Abs. Max. 328 mu



(A possible geometric isomer of A<sub>1</sub> has been isolated from shark liver oil and named galol. It crystallizes in pale yellow needles, M. P. 59-60°C. Absorption maximum 325 mu.)

**Vitamin A<sub>2</sub>**,  $\text{C}_{25}\text{H}_{42}\text{O}$   
Mol. Wt. 312.48  
Abs. Max. 345-350 mu  
(Fresh water fish oils)



**Units:** 1 United States Pharmacopoeial (USP) or 1 International Unit (IU) is the activity possessed by 0.6 mg. of pure beta-carotene.

**Standards:** Primary—pure beta-carotene. Secondary and practical standard—USP reference standard Cod Liver Oil, containing specified USP units per gram. Specially purified preparations of Vitamin A esters.

**Assay Methods:** Growth test with standardized, A-depleted rats is official for drugs. Other methods include the rat ophthalmia cure, colorimetric comparison of the blue color produced with antimony chloride, spectrophotometric measurement of ultraviolet absorption. Carotene is measured by colorimetric comparison after chromatographic or selective solvent purification.

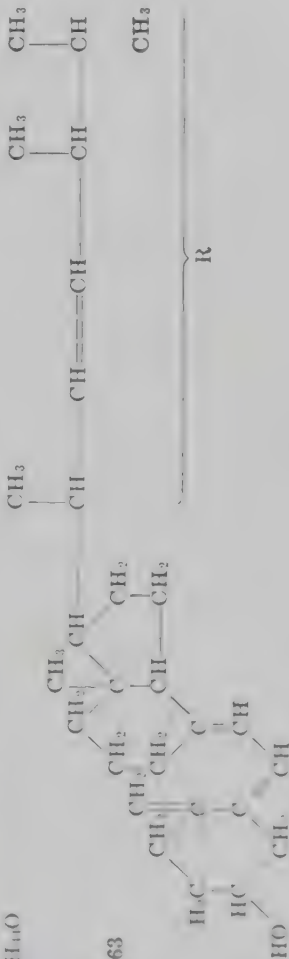



**Biological Functions:** Feeding experiments on rats indicate that Vitamin A is approximately twice as active as beta-carotene (mass basis), indicating asymmetrical fission of beta-carotene in vivo. Recent work indicates that carotene is converted to vitamin A in the wall of the intestine.

Vitamin A active substances promote growth, help maintain normal infection-resistant mucosal tissues of respiratory and other tracts, help maintain high visual acuity and adaptability to semidarkness, protect against degenerative changes in cornea and conjunctiva of the eye.

**Sources:** Green and yellow vegetables, apricots, yellow peaches, butter, cream, milk, evaporated milk, cheddar cheese, fortified margarine, eggs, liver. Cod and other fish liver oils, carotene and cereal grass concentrates are pharmaceutical sources.

TABLE 394—Continued

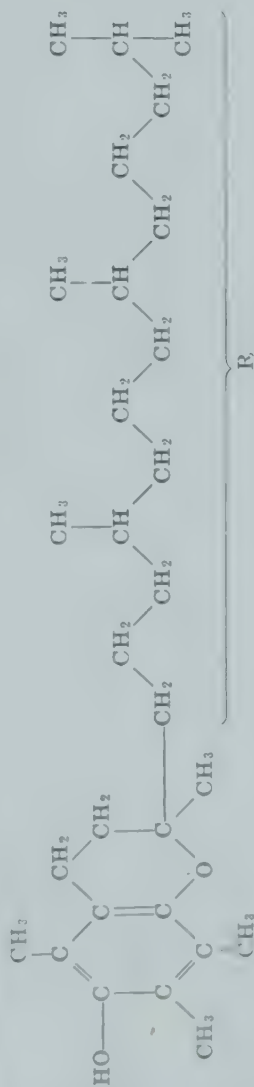
## THE FAT-SOLUBLE VITAMINS (Continued)

NAMES, FORMULAS AND CHEMICAL PROPERTIES	UNITS, ASSAY METHODS, BIOLOGICAL FUNCTIONS AND SOURCES
<p><b>VITAMIN D<sub>2</sub></b>, the antirachitic vitamin, occurs in a number of forms. Four crystalline D vitamins have been isolated and at least ten provitamins D are known. The known vitamins are white odorless crystals, soluble in fats and organic solvents and stable to heat and aeration. They exhibit characteristic absorption spectra with a maximum of 205 mμ. They have a characteristic ring structure, but differ in the side chain structure. The same is true of the provitamins D<sub>2</sub>, which are converted to D vitamins by the partial opening of the sterol ring structure to give the characteristic vitamin D structure.</p> <p>Vitamin D<sub>2</sub>; C<sub>28</sub>H<sub>44</sub>O            Calciferol            Viosterol            Activated            ergosterol            Mol. Wt. 396.63</p> 	<p>Units: 1 USP or IU is the vitamin D activity of 1 mg. International Standard Solution of irradiated ergosterol found equal to 0.025 mg. of crystalline vitamin D<sub>2</sub>. One Association of Official Agricultural Chemists (AOAC) Chick Unit of vitamin D is the antirachitic activity for the chick of a specified weight of USP reference Cod Liver Oil.</p> <p>Standards: International Standard Solution is activated ergosterol in oil. USP reference standard is Cod Liver Oil containing specified USP units per gram.</p> <p>Assay Methods: Rat curative line test is official for drugs and is used also for foods. AOAC Chick Test is used for the assay of poultry products. Measurements of antimony chloride coloration and ultraviolet absorption are used on some products, but are not applicable to most food products.</p> <p>Biological Functions: Aids in the utilization of calcium and phosphorus. Essential to development and maintenance of strong bones and teeth. Essential to prevention of rickets in children and osteomalacia in adults. Aids in preventing or curing low calcium tetanic convulsions in babies. Especially important for premature babies, for children and for pregnant and lactating women.</p> <p>Sources: Milk and evaporated milk fortified with vitamin D, fresh and canned fish, eggs. Special sources include cod liver and other fish liver oils and crystalline, synthetic Vitamin D<sub>2</sub>. Indirectly the activating action of sunshine or ultraviolet radiation on the skin produces vitamin D<sub>2</sub>.</p>
<p>Vitamin D<sub>3</sub>; C<sub>27</sub>H<sub>46</sub>O</p> <p>where R is</p> 	<p>Biological Functions: Aids in the utilization of calcium and phosphorus. Essential to development and maintenance of strong bones and teeth. Essential to prevention of rickets in children and osteomalacia in adults. Aids in preventing or curing low calcium tetanic convulsions in babies. Especially important for premature babies, for children and for pregnant and lactating women.</p>
<p>Vitamin D<sub>4</sub>; C<sub>27</sub>H<sub>46</sub>O</p> <p>where R is</p> 	<p>Sources: Milk and evaporated milk fortified with vitamin D, fresh and canned fish, eggs. Special sources include cod liver and other fish liver oils and crystalline, synthetic Vitamin D<sub>2</sub>. Indirectly the activating action of sunshine or ultraviolet radiation on the skin produces vitamin D<sub>2</sub>.</p>
<p>Vitamin D<sub>5</sub>; C<sub>29</sub>H<sub>50</sub>O</p> <p>where R is</p> 	<p>Sources: Milk and evaporated milk fortified with vitamin D, fresh and canned fish, eggs. Special sources include cod liver and other fish liver oils and crystalline, synthetic Vitamin D<sub>2</sub>. Indirectly the activating action of sunshine or ultraviolet radiation on the skin produces vitamin D<sub>2</sub>.</p>

**VITAMIN E**, the antisterility vitamin, occurs in three forms, alpha, beta and gamma-tocopherol, alpha-tocopherol being the most active biologically. All three vitamins are viscous oils, soluble in lipid solvents, insoluble in water, stable to heat in the absence of oxygen, stable to strong acids and to visible light, unstable to ultraviolet light, alkalis and oxidation. The tocopherols are antioxidants, but are destroyed by rancid fats unless protected. Esters of tocopherols are more stable than the free alcohols and have equivalent biological activity in many cases.

**Alpha-tocopherol**

$C_{28}H_{48}O_2$   
Mol. Wt. 430.69



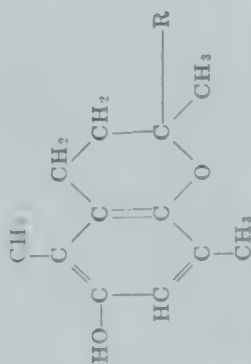
**Gamma-Tocopherol**

$C_{28}H_{48}O_2$   
Mol. Wt. 416.66



**Beta-tocopherol**

$C_{28}H_{48}O_2$   
Mol. Wt. 416.66



**Units:** 1 IU is the vitamin E activity of 0.1 gm. of International Standard Solution containing 1 mg. of pure synthetic racemic alpha-tocopherol acetate.

**Assay Methods:** Potentiometric titrations and colorimetric measurements dependent upon the oxidation of vitamin E have been used. These methods as well as the absorption spectrum measurements are subject to error from interfering compounds. In biological assays the average amount of material which will prevent resorption in rats deprived of vitamin E is measured.

**Biological Functions:** Essential for the prevention of degenerative changes in various tissues. Necessary for the integrity and proper function of reproductive, vascular and muscular tissues dependent upon the species. In rats deprived of vitamin E resorption of the partially developed fetus results in pregnant female, while sterility results in male. Muscular and reproductive tissue damage may occur in E-deficient humans. Vitamin E is believed to act as a physiological antioxidant.

**Sources:** Whole grain foods, seeds of legumes, corn and cottonseed oils, egg yolk, meats and milk. Special sources include wheat germ, wheat germ oil, oil distillates containing mixed tocopherols, and the pure substance produced synthetically.

TABLE 394—Continued

NAMES, FORMULAS AND CHEMICAL PROPERTIES	UNITS, ASSAY METHODS, BIOLOGICAL FUNCTIONS AND SOURCES
<p><b>VITAMIN K</b>, the coagulation vitamin, occurs naturally in at least two forms and possibly more. Many synthetic compounds of related chemical structure have vitamin K activity, and one of these, Menadione, is at least equivalent to vitamin K in activity and importance. The K vitamins are fat soluble, fairly stable to heat, but unstable to alkali and light. Several water-soluble derivatives of Menadione have been prepared which have vitamin K activity.</p>	<p><b>Units:</b> A unit of vitamin K is the minimum amount which will render the blood clotting of a K-depleted chick normal within six hours. Standard suggested is 1 mg. of Menadione, representing 1 unit of K activity.</p>
<p><b>Vitamin K<sub>1</sub></b>, <math>C_{40}H_{56}O_2</math> Mol. Wt. 450.68 M. P. -20°C. Yellow Oil</p>	<p><b>Assay Methods:</b> Chemical methods based on the reduction of quinone to hydroquinone structure have been used. Spectroscopic measurement can be made on pure solutions of K<sub>1</sub>, K<sub>2</sub> and Menadione. Biological assay is carried out on vitamin K-depleted chicks. The amount of test material necessary to cause the blood clotting time to return to normal (under six minutes) six hours after oral administration is determined.</p>
<p><b>Vitamin K<sub>2</sub></b>, <math>C_{41}H_{58}O_2</math> Mol. Wt. 580.86 Yellow crystalline solid M. P. 53.5-54.5°C.</p>	<p><b>Biological Functions:</b> Aids in the clotting of blood and the prevention of hemorrhage. Essential in the formation of prothrombin preliminary to the formation of blood clot. Administration of vitamin K is beneficial in prevention of intracranial hemorrhage in the newborn, in obstructive jaundice which interferes with the normal absorption of vitamin K and as preoperative precaution.</p>
<p><b>Menadione</b>, <math>C_{11}H_8O_2</math> Mol. Wt. 172.17 Yellow crystalline powder M. P. 106°C.</p>	<p><b>Sources:</b> Green leafy materials such as spinach, cauliflower, cabbage, kale, tomatoes, vegetable oils. Special sources include preparations of dried cereal grasses and alfalfa and synthetic compounds.</p>

## FOOD REQUIREMENTS FOR THE ARMY

Several basic rations have been devised and were used by the Army during World War II.

The first is known as *Field Ration A*. Designed for army men in this country, whenever practical, for men abroad, this ration is largely representative of the kind of food the average, fairly well-to-do and intelligent middle-class American family consumed before the period of civilian rationing.

*Field Ration B* came into play when men were overseas and the food became restricted to the extent that only part of the perishable items could be supplied. The *B* ration—one of nonperishables—included sugar, flour, salt and canned or dehydrated meats, fruits and vegetables, largely adjusted to suit climatic conditions, and so arranged that the menus repeated themselves on a ten-day cycle in order to prevent monotony.

TABLE 395

## NUTRITIVE VALUE OF ARMY RATIONS

	N.R.C.*	Field Ration A	Field Ration C	Field Ration K
Calories.....	4050	4300	2600-3000	3000-3400
Protein (gm.).....	70	130	120-140	115
Fat (gm.).....	.....	195	.....	.....
Carbohydrate (gm.).....	.....	510	.....	.....
Calcium (mg.).....	800	1000	500	1000
Phosphorus (mg.).....	.....	2000	.....	2000
Iron (mg.).....	12	25	27	22
Vitamin A, I.U.....	5000	13,000	2400	.....
Thiamine (mg.).....	2.15	3	1.5	3.0
Nicotinamide (mg.).....	3.12	2.8	1.6	2.5
Ascorbic acid (mg.).....	21.5	30	26	25
Thiobarbituric acid (mg.).....	75	130	27-33	55

\* National Research Council's recommendations for civilians. This is based on two-thirds extreme activity and one-third moderate activity.

Both *A* and *B* rations are for garrison duty, not for actual combat. The latter requires "operational rations."

An important "operational ration" is *Field Ration C*. Here even the field kitchen is often no longer available. One such *C* ration consists of six cans, three of which—one for each meal—are identical: biscuits, hard candy, soluble coffee and sugar. The remaining three cans—also one for each meal—are different. One contains meat and beans, the second meat and vegetable stew, and the third meat and vegetable hash.

A special emergency ration, *Field Ration D*, consists of three 4-ounce chocolate bars, plus some thiamine.

*Field Ration K*, a comparatively late product in the field, may replace *Ration C* for combat duty. The *K* ration "consists of three separate units, one for each meal. Each is packaged in a moisture-vapor-resistant, gas resistant,

nonmetallic container, and contains two different types of biscuits, canned meat or cheese, a confection, a beverage concentrate, chewing gum to allay thirst and four cigarets. The meat unit, confections and beverages are different for each of the three meals."

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## Chapter 72

### DRUGS AND THEIR DOSES

DRUGS IN the list following have been compiled from the U. S. Pharmacopoeia, Thirteenth Revision, dated April 1, 1947, and are marked U. S. P.; in New and Nonofficial Remedies, 1947, and the approved drugs as they have appeared in communications from the Council on Pharmacy and Chemistry published in the Journal of the American Medical Association marked N.R., along with certain additions from the literature without specific marking.

The single dose notation of the United States Pharmacopoeia has not been followed. Instead, the usual limits of a single dose, the interval between doses, the relationship to meals, or the amount of drug ordinarily needed in twenty-four hours have been noted. In some cases drugs should be used for relatively short periods, e. g., ten to fourteen days, and these have been noted. Metric dosage is preferred, but apothecaries' dosage also is given.

Doses of medicine for children may be estimated by Young's rule: The age of the child divided by the age plus twelve gives a fraction which represents the portion of the adult dose to be used. Preferable, however, is Clark's rule, in which the weight of the child is divided by 150, thus forming a fraction which represents the portion of the adult dose for the child in question. These rules do not hold for opium or any of its derivatives. Children are susceptible to overdoses and can safely take but one-half or one-third of the estimated dose. Otherwise, the child generally does not follow the rule with laxatives, about one-third more than the estimated dose being needed.

The hypodermic dose is usually one-half to two-thirds of the oral dose; the rectal dose is half again as much or twice the oral dose.

An effort has been made to make a comparative table of the local anesthetics, their particular uses, limitations and characteristics, the data being obtained from New and Nonofficial Remedies, 1947, the United States Dispensary, 1942 edition, and The Pharmacological Basis of Therapeutics.\*

Subq. means subcutaneously

I.M. means intramuscularly

I.V. means intravenously

Antifebrin, U.S.P. (Antifebrin): 0.1 to 0.2 gm. (1½ to 3 grains), three or four times daily.  
Arsone, N.N.R. (27.1% arsenic) (Stovarsol): oral, 0.25 gm. (4 grains), two or three times daily for seven days.

Phenetidin, U.S.P. (Phenacetin): 0.3 gm. (5 grains), three or four times daily.

β-methylcholine } See *Methacholine Chloride*.  
β-methylcholine Chloride }

Salicylic Acid, U.S.P. (Aspirin): 0.3 gm. (5 grains) up to 6 gm. (90 grains) per day.

in: see *Carbromal*.

\* Goodman, L., and Gilman, A., New York, The Macmillan Company, 1941.

Adrenal Cortex Extract Solution, N.N.R. Eschatin: I.M. or I.V., 2 to 10 cc. or more at 50 dog units per ml. (Pfiffner, Swingle and Vars (J. Biol. Chem., 104:701, 1934).

Afenil: see *Calcium Chloride Urea*.

Agar, U.S.P.: 4 gm. (1 drachm) daily.

Allergenic Extracts: Material used by contact with skin or conjunctiva or by injection into the skin for diagnosis or for the treatment of persons subject to diseases characterized by hypersensitiveness. Preparation of the material depends upon and varies with its source. Its standardization should be gauged by its nitrogen content or by the amount of material in the extract. Graduated doses must be used for treatment. In every case there should be first a test dose into the skin (0.01 or 0.02 cc.) of a very weak solution to determine through size of the wheal formed the sensitivity of the individual. The physician using these preparations should have at hand a hypodermic syringe of 1:1000 epinephrine solution.

Aloe, U.S.P.: 0.03 to 0.25 gm. ( $\frac{1}{2}$  to 4 grains) at night.

Aloin, U.S.P.: 5 to 20 mg. ( $\frac{1}{12}$  to  $\frac{1}{3}$  grains) at night.

Aluminum Hydroxide Gel, U.S.P. (Collodial Aluminum Hydroxide): 8 cc. (2 fluidrachms) after meals.

Aluminum Hydroxide Gel, Dried, U.S.P.: 0.6 gm. (10 grains) after meals.

Alurate, N.N.R.: 30 to 65 mg. ( $\frac{1}{2}$  to 1 grain) after meals or at bedtime.

Alurate Sodium, N.N.R.: 10 mg. per kilogram of body weight by mouth or rectum.

Amino Acids, N.N.R. (Amigen): I.V. or oral, 1 gm. per kilogram of body weight.

Aminophylline, U.S.P. (Theophylline ethylenediamine) (Metaphyllin): Oral, 0.1 to 0.2 gm. ( $1\frac{1}{2}$  to 3 grains) three or four times daily; I.V., 0.2 to 0.5 gm. (3 to 7 $\frac{1}{2}$  grains).

Aminopyrine, U.S.P. (Amidopyrin): 0.13 to 0.3 gm. (2 to 5 grains) three or four times daily with caution.

Ammonium Carbonate, U.S.P. (Sal Volatile): 0.3 gm. (5 grains) three to six times daily.

Ammonium Chloride, U.S.P.: 0.3 to 1 gm. (5 to 15 grains) three or four times daily.

Ammonia, Aromatic Spirit, U.S.P.: 2 cc. (30 minims), diluted.

Amphetamine Sulfate, N.N.R. (Benzedrine): 2.5 to 10 mg. ( $\frac{1}{30}$  to  $\frac{1}{6}$  grain) twice or three times before 4 P. M.

Amyl Nitrite, U.S.P.: 0.2 cc. (3 minims) by inhalation.

Amytal, N.N.R.: 0.1 to 0.3 gm. ( $1\frac{1}{2}$  to 5 grains) at bed time.

Amytal Sodium, N.N.R.: I.V., 0.2 to 0.5 gm. (3 to 7 $\frac{1}{2}$  grains) in 2 per cent solution.

Anhydrohydroxyprogesterone, U.S.P. (Pranone) (Progestoral): Oral, 10 mg. ( $\frac{1}{6}$  grain) daily.

Antianthrax Serum, N.N.R.: I.M. or I.V., 50 cc. and more daily.

Antidysenteric Serum, N.N.R.: 20 to 100 cc. Subq. or I.M. The serum must show a high agglutination titer for various types of dysentery bacilli.

Antierysipeloid Serum, N.N.R. (for erysipeloid): Serum to be of a potency such that 0.1 cc. protects pigeons against infection lethal to controls in three to four days. Dose, 10 to 20 cc. Subq. or I.M. and small amounts (0.3 cc.) injected at the border of the lesion in numerous places.

Antimeningococcic Serum, N.N.R.: I.V., 50 to 100 cc.; Intrathecal, 30 cc.

Antipneumococcus Serum (Horse) (various types), N.N.R.: I.M. or I.V., 20 to 40 cc.

Antipneumococcus Serum (Rabbit) (various types), N.N.R.: I.M. or I.V., 20 to 40 cc.

Antimony Potassium Tartrate, U.S.P. (Tartar Emetic): Oral, 1 mg. ( $\frac{1}{60}$  grain) every four hours; I.V., 30 to 150 mg. ( $\frac{1}{2}$  to 2 $\frac{1}{2}$  grains) every other day.

Antimony Sodium Thioglycollate, U.S.P.: I.V., 50 mg. ( $\frac{3}{4}$  grain) every three or four days for 15 to 20 doses.

Antivenin Crotalus (N. American Snakes), N.N.R.: I.M. or I.V., 50 cc. and more.

Antivenin Latrodectus Mactans (Black Widow), N.N.R.: I.M., 2.5 cc.

Apomorphine Hydrochloride, U.S.P.: Expectorant, 1 mg. ( $\frac{1}{60}$  grain); emetic, Subq., 5 mg. ( $\frac{1}{12}$  grain).

Arsphenamine, U.S.P. (Salvarsan): I.V., 0.2 to 0.6 gm. (3 to 9 grains). Specially prepared alkalized solution in dilution of 25 cc. per 0.1 gm. to be injected slowly.

Ascorbic Acid, U.S.P.: 25 to 100 mg. ( $\frac{3}{8}$  to 1 $\frac{1}{2}$  grains) three times daily. Normal need per day, 75 mg.

Sodium Ascorbate Injection, U.S.P.: I.V., 100 mg. (1 $\frac{1}{2}$  grains daily).

Aspidium, Oleoresin, U.S.P. (Male Fern): 4 gm. (60 grains) single dose.

Atabrine: see *Quinacrine Hydrochloride*.

Atropine Sulfate, U.S.P.: 0.5 mg. ( $\frac{1}{120}$  grain) three times daily.

tal, U.S.P. Veronal : 0.3 gm. (5 grains) — may be repeated at bed time.  
 tal Sodium, U.S.P. Medinal : 0.3 gm. (5 grains) at bed time.  
 m Sulfate, U.S.P.: For x-ray opaque diagnostic meal or enema, 60 to 200 gm. (2 to 8 ounces).  
 donna Extract, U.S.P.: 15 mg. ( $\frac{1}{4}$  grain) three times daily.  
 donna Ointment, U.S.P.: 10 per cent extract, mainly hemorrhoids.  
 donna Tincture, U.S.P.: 0.6 cc. (10 minims) three or four times daily.  
 dryl: 50 to 100 mg. ( $\frac{3}{4}$  to  $1\frac{1}{2}$  grains) daily.  
 estrol, N.N.R. (Octofollin) (Estrogen): Oral and I.M., 2 to 5 mg. ( $\frac{1}{32}$  to  $\frac{1}{12}$  grain) daily for four to seven days.  
 oin, Compound Tincture, U.S.P.: Inhalant, 4 cc. (1 drachm) in hot water. Locally painted on skin or mucous membrane.  
 yl Benzoate, Saponated, U.S.P.: Apply to skin after soft soap scrub and thorough soak.  
 naphthol, U.S.P.: 0.13 gm. (2 grains) every four hours.  
 Salts: see *Ox Bile Extract*.  
 arsen, N.N.R. (Sulpharsphenamine Bismuth): I.M., 0.1 and 0.2 gm. ( $1\frac{1}{2}$  and 3 grains) once weekly for 20 doses.  
 o-Cymol, N.N.R. (Bismuth Camphocarboxylate): In oil, I.M., 0.05 to 0.1 gm. ( $\frac{3}{4}$  to  $1\frac{1}{2}$  grains) twice weekly.  
 osol, N.N.R. (35 per cent Bismuth): I.M., 1 cc. (15 minims) every two days to 20 doses.  
 uth Ethylcamphorate, N.N.R.: In oil, 2 cc. (30 minims) once each week.  
 uth Potassium Tartrate, U.S.P.: I.M., 0.1 to 0.2 gm. ( $1\frac{1}{2}$  to 3 grains) at weekly intervals.  
 uth Subcarbonate, U.S.P.: 1 gm. (15 grains) several times daily.  
 uth Subsalsicylate, U.S.P.: In oil, I.M., 0.1 gm. ( $1\frac{1}{2}$  grains) once weekly.  
 olism Antitoxin, N.N.R.: Prophylactic, 2500 units; therapeutic, 10,000 units.  
 mural, N.N.R.: 0.3 gm. (5 grains) three times daily.  
 cella Vaccine, N.N.R. (*Br. abortus* 8, *Br. suis* 5 to 6 billion per cubic centimeter): 0.1 cc. increasing at five-day intervals.  
 cella Vaccine, N.N.R. (*Br. melitensis* 2 billion per cubic centimeter): 0.1 cc., increasing at 5 day intervals.  
 bot Liver Oil, N.N.R.: 1 cc. (15 minims). Potency, Vitamin A, 4480 units; Vitamin D, 640 units.  
 eine, U.S.P.: 0.2 gm. (3 grains) several times daily.  
 eine Citrated, U.S.P.: 0.3 gm. (5 grains) several times daily.  
 eine and Sodium Benzoate, U.S.P.: I.M., 0.5 gm. ( $7\frac{1}{2}$  grains) every four hours.  
 ciferol: See *Vitamin D<sub>2</sub>*.  
 cium Carbonate, Precipitated, U.S.P. (Precipitated Chalk): 1 gm. (15 grains) three times a day.  
 cium Chloride Urea, N.N.R. (Afenil): I.V., 10 cc. ampule, equivalent to 0.11 gm. of calcium daily.  
 cium Gluconate, U.S.P.: Oral, 5 gm. (75 grains) three times a day; I.V., 1 gm. (15 grains) daily to every three days.  
 cium Hydroxide Solution, U.S.P. (Limewater): 15 cc. (4 fluidrachms).  
 cium Iodobehenate, U.S.P. (Sajodin): 65 mg. to 0.5 gm. (1 to  $7\frac{1}{2}$  grains) three times a day.  
 cium Lactate, U.S.P.: 5 gm. (75 grains) three times a day.  
 cium Pantothenate: 10 to 25 mg. ( $\frac{1}{6}$  to  $\frac{3}{8}$  grains) three times a day.  
 cium Phosphate, Dibasic, U.S.P.: 1 gm. (15 grains) three times a day.  
 phor, U.S.P.: Oral or I.M., in oil, 0.2 gm. (3 grains) every four hours.  
 bachol, U.S.P. (Doryl) (Lentine): Subq., 0.25 mg. ( $\frac{1}{250}$  grain); Oral, 2 mg. ( $\frac{1}{50}$  grain).  
 arsone (28.6 per cent Arsenic): 0.2 gm. (3 grains) twice daily for ten days.  
 on Tetrachloride, N.N.R.: Single dose, 2 cc. (30 minims) in capsules, to be followed in two or three hours by a "saline" purge. Caution.  
 promal, N.N.R. (Adalin): 0.3 gm. (5 grains) at bed time.  
 otene in Cottonseed Oil, N.N.R.: Potency — each gram contains 7500 units of vitamin A. Adult normal need of vitamin A per day is 5000 units; children, 1500 to 5000 units.  
 otene with Vitamin D in Oil, N.N.R.: Potency — vitamin A, 7500 units; vitamin D, 1000 units.  
 ara Sagrada Extract, U.S.P.: 0.3 gm. (5 grains); usually 1 dose at bed time.  
 ara Sagrada Fluidextract, U.S.P.: 1 cc. (15 minims); usually 1 dose at bed time.  
 ara Sagrada Aromatic Fluidextract, U.S.P.: 2 cc. (30 minims); usually 1 dose at bed time.

Castor Oil, U.S.P.: 15 to 30 cc. (4 to 8 fluidrachms); 1 dose.

Chalk Mixture, U.S.P.:

Prepared Chalk	60.	} 15 cc. (4 fluidrachms).
Saccharin Sodium	0.3	
Bentonite Magma	500.	
Cinnamon Water	400.	

Distilled water enough to make 1000 cc.

Chiniofon, U.S.P. (Yatren): 0.25 to 1 gm. (4 to 15 grains) three times daily for one week.

Chloral Hydrate, U.S.P.: 0.6 gm. (10 grains), repeated once if necessary.

Chlorobutanol, U.S.P.: 0.6 gm. (10 grains), repeated once if necessary.

Cholera Vaccine, U.S.P.: For active immunization, 8 billion per cubic centimeter; 3 doses, 1.0, 1.0 cc. at intervals of seven to ten days.

Chorionic Gonadotropin, N.N.R. (Antuitrin S, A.P.L. Anteron, Follutein, Korotrin, Pranturon) 100 to 10,000 international units in preparation diluted with 10 cc. of water.

Cincophen, N.N.R. (Atophan): 0.5 gm. (7½ grains) three or four times daily.

Cocaine, U.S.P.: Rarely internally; oily solution, 0.5 per cent.

Cocaine Hydrochloride, U.S.P.: Rarely internally, 15 mg. (¼ grain); solution, 0.5 per cent.

Cod Liver Oil, U.S.P.: 8 cc. (2 fluidrachms). In each gram not less than 850 U.S.P. units vitamin A and 85 U.S.P. units of vitamin D. Once daily.

Cod Liver Oil Emulsion, U.S.P.: 15 cc. (4 fluidrachms) twice or thrice daily.

Codeine Phosphate, U.S.P.: Subq., 30 mg. (½ grain).

Codeine Sulfate, U.S.P.: Oral, 8 to 30 mg. (⅛ to ½ grain).

Colchicine, U.S.P.: 0.5 mg. (1/120 grain) every four hours to nausea or purging.

Corpus Luteum: See *Anhydrohydroxyprogesterone* and *Progesterone*.

Dehydrocholate Sodium Solution, 20 per cent, N.N.R. (Decholin Sodium: I.V., 5 to 10 cc. given on each of three successive days.

Dehydrocholic Acid, N.N.R. (Decholin (Cholan D.H.): 0.25 gm. (4 grains) two or three times daily after meals.

Demerol Hydrochloride, N.N.R. (Meperidine): 50 to 100 mg. (¾ to 1½ grains).

Desoxycorticosterone Acetate, U.S.P. (Cortate, Percorten) in oil: I.M., daily 2 to 30 mg. or more (⅓ to ½ grain). Also by implantation—100 mg. pellet.

Dextrose, U.S.P.: I.V., 5 per cent in 500 cc. of water or normal saline, or 50 per cent in 50 cc. of water.

Dichlorophenarsine Hydrochloride, U.S.P. (Clorarsen) (Arsenic 26 per cent: I.V., 45 to 60 mg. (⅔ to 1 grain) at intervals of five to seven days.

Dicoumarol, 300 mg. per day or less, depending upon daily estimation of prothrombin time; heparin preferred.

Diethylstilbestrol, U.S.P. (Stilbestrol): Oral, 0.5 mg. (1/120 grain); in oil, subq., 0.5 mg. (1/120 grain).

Digitalis, U.S.P. (Digitalis Purpurea): 0.1 gm. (1½ grains) daily. 0.1 gm. equals 1 U.S.P. digitalis unit maintenance dose.

Digitalis Injection, U.S.P. (Digalen, Digifolin, Digipoten): I.M., 1 cc. equals 1 U.S.P. unit (½ U.S.P. unit).

Digitalis Tincture, U.S.P.: 1 cc. (15 minims) daily maintenance dose.

Digitoxin Injection, U.S.P. (from Digitalis Purpurea): I.V., 0.1 mg. (1/600 grain).

Digoxin Injection, U.S.P. (from Digitalis Lanata): Subq., 0.5 mg. (1/120 grain) maintenance dose.

Dihydromorphinone Hydrochloride, U.S.P. (Dilaudid): 2 mg. (1/30 grain) repeated for pain.

Dihydroxytachysterol (Hytakerol): 1 cc. ampule contains 1.25 mg. of drug.

Dilantin: See *Diphenylhydantoin Sodium*.

Dilaudid: See *Dihydromorphinone Hydrochloride*.

Diphenylhydantoin Sodium, U.S.P. (Dilantin): 0.1 gm. (1½ grains) two or three times daily.

Diphtheria Antitoxin, U.S.P.: For passive immunity. Prophylactic, 1000 units; treatment, 20,000 and up. Unit is that amount of antitoxin which will just neutralize 100 minimum lethal doses (M.L.D.) of freshly made standard diphtheria toxin. The M.L.D. is the smallest amount of toxin administered subcutaneously to a 250 to 300 gm. guinea pig which will cause death within ninety-six hours.

Diphtheria Toxin, U.S.P., for Shick test: Intracutaneous. Solution of such strength that 0.1 cc. of the dose contains 1/50 M.L.D.

Diphtheria Toxin-Antitoxin, N.N.R.: For active immunity, 1 cc. Subq. at weekly intervals, 3 doses. Each cubic centimeter represents 0.1 lethal dose for guinea pig neutralized with proper amount of diphtheria antitoxin.

quin, N.N.R.: Oral, 0.21 gm. (3 grains) tablets; seven to ten tablets daily for fifteen to twenty days.

Theria Toxoid, U.S.P.: For active immunity—0.5, 1.0 and 1.0 cc. Subq. at monthly intervals. Products of growth of diphtheria so modified as to have lost ability to cause toxic effects, but retaining the property of inducing active immunity. The toxicity is so low that five times the initial dose for humans does not cause local or general symptoms of diphtheria poison in a guinea pig within thirty days. The antigenic value must be such that the initial dose will protect 80 per cent of guinea pigs six weeks after injection against five M.L.D. of diphtheria test toxin.

Theria Toxoid, Alum Precipitated, U.S.P.: For active immunity—0.5, 1 and 1 cc. Subq. at intervals of four to six weeks. This toxoid is of such strength that the initial dose in a 500 gm. guinea pig shall produce 2 units of antitoxin per cubic centimeter of blood serum in four weeks.

Theria and Tetanus Toxoids, U.S.P.: Subq. for active immunity against diphtheria and tetanus. Dosage, 1 cc., repeated twice at three week intervals.

Theria and Tetanus Toxoid, Alum Precipitated, U.S.P.: Subq. for active immunity against diphtheria and tetanus. Dosage, 1 cc. and 1 cc. in six to eight weeks.

Effervescent Powders, Compound, U.S.P. (Seidlitz): White powder, tartaric acid, about 2 gm. (30 grains); blue powder, bicarbonate of soda, about 2.5 gm. (40 grains) and potassium and sodium tartrate, 7.5 gm. (2 drachms). One white and one blue powder dissolved separately, mixed, and taken as one dose when effervescence subsides.

Ephedrine Hydrochloride, U.S.P.: I.M., local and oral, 30 to 60 mg. ( $\frac{1}{2}$  to 1 grain) daily for 12 to 14 doses.\*

Ephedrine Hydrochloride, U.S.P.: Local,  $\frac{1}{2}$  to 3 per cent; 25 mg. ( $\frac{3}{8}$  grain) two or three times a day for asthma.

Ephedrine Sulphate, U.S.P.: Oral, 25 mg. ( $\frac{3}{8}$  grain) three times daily.

Ephedrine Inhalation, U.S.P.: 1:100, cautiously inhaled by nebulizer only.

Ephedrine Injection, U.S.P.: 1:1000 solution, 0.3 to 1 cc. = 0.5 to 1 mg. ( $\frac{1}{120}$  to  $\frac{1}{60}$  grain) several times daily up to hourly doses.

Ephedrine Solution, U.S.P.: 1:1000 for local application.

Novovine Malleate, U.S.P.: I.V. or I.M., 0.2 mg. ( $\frac{1}{300}$  grain); oral, 0.5 mg. ( $\frac{1}{20}$  grain) three times daily.

Amphetamine Tartrate, U.S.P. (Gynergen): I.M., 0.25 mg. ( $\frac{1}{240}$  grain); oral, 1 mg. ( $\frac{1}{60}$  grain) three times daily.

Amphetamine Tetranitrate, U.S.P.: 15 to 60 mg. ( $\frac{1}{4}$  to 1 grain) every four hours.

Progynon Benzoate, U.S.P. (Progynon B, Dimenformin pro-follin): I.M., 1 mg. ( $\frac{1}{60}$  grain) twice weekly.

Progynon, U.S.P. (Dihydrotheelin): 0.2 mg. ( $\frac{1}{300}$  grain).

Theelol, N.N.R. (Theelol): Oral, 0.12 to 0.24 mg. ( $\frac{1}{600}$  to  $\frac{1}{250}$  grain) one to four times daily.

Amnionin, U.S.P. (Amnionin, Emmenin) (Theelin): I.M., 1 mg. ( $\frac{1}{60}$  grain) weekly.

Amnioninobenzoate, U.S.P. (Anesthesin): 0.3 gm. (5 grains); repeat as needed.

Amnioninmoograte: Oral, 1 cc. (15 minims); I.M., 1 cc. to 3 or 4 cc.

Amnioninmorphine Hydrochloride, U.S.P. (Dionin): 15 mg. ( $\frac{1}{4}$  grain); repeat for cough and pain.

Locally in eye, 1 to 10 per cent solution.

Amnionin: See *Liver with Stomach*.

Bovis: See *Ox Bile*.

Ammonium Citrate, U.S.P.: 1 gm. (15 grains) three times daily.

Ammonium Sulfate, U.S.P. (Feosol): 0.3 gm. (5 grains) three times daily.

Ascorbic Acid: 20 mg. ( $\frac{1}{3}$  grain) daily.

Ascorbic Acid, N.N.R. (Stibophen): I.M., I.V.: Solution, each cubic centimeter contains Fuadin, 64 mg. of sodium bisulphite, 0.125 per cent. Dose,  $1\frac{1}{2}$  to 5 cc., alternate days for 9 doses—then, after a rest, repeat the course and then dose every two weeks for four to six weeks.

Ascorbic Acid, Gangrene Antitoxin, Bivalent, U.S.P.: For passive immunity. Serum of horses immunized against *Clostridium perfringens* and *Cl. septicum*: 10,000 units, repeated.

Ascorbic Acid, Gangrene Antitoxin, Pentavalent, U.S.P.: Dose, 10,000 units and up. Horse serum contains 10,000 units each of *Clostridium perfringens* and *Cl. septicum*, 1500 units of *Cl. oedematis* and *Cl. fermentum* and 3000 units of *Cl. histolyticum*.

Ascorbic Acid, Gangrene Antitoxin, Trivalent, U.S.P.: Horse Serum contains antitoxin of *Clostridium perfringens* and *Cl. septicum*, each 10,000 units, and *Cl. oedematis*, 1500 units.

\* Emetine Bismuth Iodide, British Pharmacopeia, in doses of 60 to 200 mg. (1 to 3 grains) orally three times daily is effective in amebiasis.

- Globulin, Human Immune, U.S.P.: Dose, 2 to 10 cc. A sterile solution of antibodies obtained from the pooled material from placentae expelled by at least ten healthy women.
- Glyceryl Trinitrate, U.S.P. (Nitroglycerine) (Glonoin): 0.4 mg. ( $\frac{1}{150}$  grain) every half to two hours as needed.
- Glycotauro: See *Ox Bile Extract*.
- Gold Sodium Thiosulfate, N.N.R. (Sancocrysin): I.M., 10 to 50 mg. ( $\frac{1}{4}$  to  $\frac{3}{4}$  grains) weekly.
- Gonadotropin, Chorionic, N.N.R. (Choriogonin) (Follutein) (Korotrin): I.V.: vials containing dry chorionic gonadotropin with urea and sodium phosphate to be dissolved in 10 cc. water. Dose, 200 to 500 units twice each week.
- Halibut Liver Oil, U.S.P.: Not less than 60,000 U.S.P. units of vitamin A and not less than 600 units of vitamin D in each gram. Infants, 6 to 10 drops daily. Severe deficiencies, 20 drops or more daily.
- Halibut Liver Oil with Viosterol, N.N.R.: Not less than 60,000 units of vitamin A and 10,000 units of vitamin D per gram; infants, 8 to 10 drops; nursing or expectant mothers, 20 drops daily.
- Heparin Sodium, N.N.R.: I.V., 50 mg. ( $\frac{3}{4}$  grain) every four hours; I.V. drip, 100 to 200 mg. in 1000 cc. of 5 per cent sterile dextrose—20 drops per minute.
- Hexamine: See *Methenamine*.
- Hexavitamin Tablets, U.S.P.: Each tablet to contain vitamin A, 5000 U.S.P. units; vitamin D, 400 U.S.P. units; ascorbic acid, 75 mg.; thiamin chloride, 2 mg.; riboflavin, 3 mg.; nicotinamide, 20 mg. Tablet daily.
- Hexobarbital Soluble, N.N.R. (Evipal Soluble): I.V., for rapid, short term general anesthesia, 10 per cent solution, 2 to 4 cc.
- Hexylresorcinol, U.S.P.: As anthelmintic, 1 gm. (15 grains), single dose.
- Histamine Phosphate, U.S.P.: 0.2 to 0.5 mg. ( $\frac{1}{300}$  to  $\frac{1}{120}$  grain) one to four times daily.
- Homatropine Methylbromide, N.N.R. (Novatropine) (Mesopin): 2.5 mg. ( $\frac{1}{25}$  grain), 1 or 2 tablets before meals.
- Hydriodic Acid, Syrup, U.S.P.: 4 cc. (1 fluidrachm) three times daily.
- Hydrochloric Acid, Dilute, U.S.P.: 2 cc. (30 minims) three times daily with meals.
- Hyoscine Hydrobromide: See *Scopolamine*.
- Hyoscyamus Tincture, U.S.P.: 2 cc. (30 minims) three or four times daily.
- Insulin, U.S.P.: Prepared in solution of 20, 40, 80 or 100 units of insulin per cubic centimeter for subcutaneous or intravenous injection. For ordinary use the solution chosen is that one which will furnish the required insulin units in about 0.5 cc., the dose being always expressed in units. It is given subcutaneously a half hour before meals, and the effect is most intense in two to three hours. For coma, these solutions are used intravenously or subcutaneously.
- Insulin Crystalline with Zinc, N.N.R.: 20, 40 and 80 units per cubic centimeter. Used in a manner similar to insulin. Because of its chemical purity, it is especially useful for patients who may be allergic to insulin.
- Insulin Globin with Zinc, N.N.R.: 40 and 80 units per cubic centimeter, prepared with globin (from hemoglobin of beef blood), 3.6 mg., and zinc, 0.25 to 0.35 mg. per 100 units, with not more than 1.50 mg. total nitrogen. It contains also 1.3 to 1.7 per cent of glycerin and a small amount of phenol or cresol. It is stable, can be used only subcutaneously—never intravenously—and its largest effect is eight to sixteen hours after injection.
- Insulin, Protamine Zinc, U.S.P.: Each cubic centimeter of this preparation contains 40 units of insulin, 0.4 to 0.6 mg. of protamine, 0.08 to 0.1 mg. of zinc, 1.6 per cent glycerine, a small amount of cresol or phenol and sufficient acid sodium phosphate to maintain the pH at about 7.2. The greatest effect of this preparation is twelve to twenty-four hours after injection, and its chief advantage is that usually but one dose each day is needed. This solution cannot be used intravenously.
- Intocostin, N.N.R. (Curare): I.V. solution, 1 cc., equivalent to 20 units. Dose is 0.5 unit per pound of body weight; and on initial dose less than this amount; less for anesthesia.
- Iodine, Strong Solution, U.S.P. (Lugol's Solution): 0.3 cc. (5 minims) three times daily. Represents about 15 mg. of iodine per dose.
- Iodobismutol with Benzocaine, N.N.R.: I.M., 2 cc. ampule given twice weekly contains sodium iodobismuthite, 0.12 gm., sodium iodide, 0.24 gm., benzocaine, 80 mg., and propylene glycol, qs to 2 cc.
- Ipecac Syrup, U.S.P.: 8 cc. (2 fluidrachms) as emetic single dose.
- Ipral Calcium, N.N.R.: 50 mg. to 0.13 gm. ( $\frac{3}{4}$  to 2 grains) at bed time.
- Lanatoside C, U.S.P. (From Digitalis Lanata): Oral or Subq., 0.4 to 0.8 mg. ( $\frac{1}{100}$  to  $\frac{1}{25}$  grain) daily.

azol: See *Metrazol*.

dol, N.N.R.: 0.5 gm. ( $7\frac{1}{2}$  grains) in capsules, 2-5 capsules after each meal.

Extract, U.S.P. The minimum dose per day, whether oral or intramuscular, is 1 U.S.P. unit. The U.S.P. unit is that amount of an otherwise acceptable product which produces . . . responses . . . considered by the Anti-anemia Board to be satisfactory. Usually larger doses are given.

Injection, U.S.P.

Solution, U.S.P.

with Stomach, U.S.P. (Extralin): Average daily oral dose, 1 U.S.P. unit.

nesia Magma, U.S.P. (Milk of Magnesia): 4 cc. (1 fluidrachm; laxative, 15 cc. (4 fluidrachms).

nesium Carbonate, U.S.P.: 0.6 gm. (10 grains) three times daily.

nesium Citrate Solution, U.S.P.: 200 cc. (7 fluid ounces), single dose.

nesium Oxide, U.S.P.: 0.5 gm. ( $7\frac{1}{2}$  grains) three times daily.

nesium Oxide Heavy, U.S.P.: 0.5 gm. ( $7\frac{1}{2}$  grains) three times daily.

nesium Phosphate Tribasic, N.N.R.: 0.6 to 2 gm. (10 to 30 grains) three times daily.

nesium Sulfate, U.S.P. (Epsom Salt): 15 gm. (4 drachms), one dose.

nesium Trisilicate, U.S.P.: 1 gm. (15 grains) after meals.

ndelic Acid, N.N.R.: 3 gm. (45 grains) three times daily; urine acidity to be 5.5 pH.

nitrol Hexanitrate, N.N.R.: 15 to 60 mg. ( $\frac{1}{4}$  to 1 grain) every four to six hours.

pharsen: See *Oxyphenarsine Hydrochloride*.

asles Immune Serum, Human, N.N.R.: I.M., to prevent or modify the disease; dose, 10

to 20 cc. From bloods of healthy persons who have recently recovered from measles.

cholyl Chloride: See *Methacholine Chloride*.

cholyl Bromide, N.N.R.: Oral, 0.2 to 0.6 gm. two or three times daily.

dinal: See *Barbital Sodium*.

nadione, U.S.P. (Vitamin K): Oral, 1 mg. ( $\frac{1}{60}$  grain) per day.

nadione Sodium Bisulfite, U.S.P.: I.M. or I.V., 2 mg. ( $\frac{1}{30}$  grain), may be repeated daily.

rcuhydrin Sodium Solution, N.N.R.: Each cubic centimeter contains 176 mg. of mercurhydrin

and 78 mg. of theophyllin. Dose, 1 or 2 cc. I.V. or I.M. twice weekly.

rcurial Ointment Mild, U.S.P.: Local paraciticide.

rcurial Ointment Strong, U.S.P.: 4 gm. (1 drachm) daily by inunction.

rcurophylline Injection, U.S.P. (Mercupurin): Dose in 1 or 2 cc. equals mercury compound,

0.1 to 0.2 gm. ( $1\frac{1}{2}$  to 3 grains) and Theophylline, 40 to 80 mg. ( $\frac{2}{3}$  to  $1\frac{1}{3}$  grains), with

caution.

ercurous Chloride, Mild, U.S.P. (Calomel): 0.13 gm. (2 grains) in divided doses.

ercuric Salicylate, N.N.R.: I.M. in oil, 60 to 100 mg. (1 to  $1\frac{1}{2}$  grains) twice weekly.

ercuric Succinimide, N.N.R.: I.M., 10 to 20 mg. ( $\frac{1}{6}$  to  $\frac{1}{3}$  grain) daily.

ersalyl and Theophylline, U.S.P. (Salyrgan-Theophylline): Oral, 80 mg. of mersalyl and

40 mg. of theophylline per tablet; 2 tablets once daily. I.M., I.V. ampules, 1 and 2 cc. Each

cubic centimeter contains mersalyl, 0.1 gm., and theophylline, 50 mg. Dose, usually 2 cc.

every two to seven days with caution.

etacholine Chloride, U.S.P. (Mecholyl Chloride): Oral, 0.2 gm. (3 grains) up to 2 gm. (30

grains) per day; Subq., 10 mg. ( $\frac{1}{6}$  grain). For local effect, by iontophoresis to the part.

etamucil, N.N.R.: 4 to 7 gm. (1 to 2 drachms).

ethenamine, U.S.P. (Hexamine) (Urotropin): 0.3 to 0.5 gm. (5 to  $7\frac{1}{2}$  grains) three or four

times daily.

ethyl Salicylate, U.S.P. (Oil of Gaultheria): Locally with rubbing; oral, 0.6 cc. (10 minims)

four to six times a day.

ethylene Blue, U.S.P.: 0.15 gm. ( $2\frac{1}{2}$  grains) several times daily.

ethylrosaniline Chloride, U.S.P. (Gentian Violet): Oral, 60 mg. (1 grain) three times daily;

locally, 1:1000 solution.

etrazol, N.N.R. Leptazol: I.M., Subq. or I.V., 1 cc. and 2 cc. ampules. Each cubic centimeter

contains 0.1 gm. of metrazol. 0.1 gm. ( $1\frac{1}{2}$  grains), repeated as required.

ethyltestosterone, U.S.P. (Metandren, Oreton M): Oral, 10 mg. ( $\frac{1}{6}$  grain); sublingual, 5 mg.

( $\frac{1}{12}$  grain) up to 40 mg. per week.

orphine Sulfate, U.S.P.: 10 to 15 mg. ( $\frac{1}{6}$  to  $\frac{1}{4}$  grain). Repeat if needed.

aphuride Sodium: See *Suramin Sodium*.

eoarsphenamine, U.S.P. (Neosalvarsan): 0.45 to 0.6 gm. ( $7\frac{1}{2}$  to 10 grains) once weekly in

freshly prepared solution.

eo cinchophen, U.S.P. (Tolylin): 0.3 gm. (5 grains) three times daily with caution.

eonol, N.N.R.: 50 mg. to 0.4 gm. ( $\frac{3}{4}$  to 6 grains).

eo stigmine Bromide, U.S.P. (Prostigmine): 15 mg. ( $\frac{1}{4}$  grain) three times daily.

- Neostigmine Methylsulphate, U.S.P.: In ampules, each 1 cc.; 1:4000 equals 0.25 mg. (1/200 grain); 1:2000 equals 0.5 mg. (1/120 grain).
- Neosynephrine Hydrochloride, N.N.R.: Local, 1% per cent.
- Nicotinamide, U.S.P. (Niacinamide): Oral and Subq., 25 to 100 mg. (3/8 to 1 1/2 grains) three times daily.
- Nicotinic Acid, U.S.P. (Niacin): Oral, 25 to 100 mg. (3/8 to 1 1/2 grains) three times daily.
- Nikethamide, N.N.R. (Coramine): I.M. or I.V. solution, 25 per cent, 1.5 or 2 cc.
- Novatropine: See *Homatropine Methylbromide*.
- Oleovitamin A, U.S.P.: Daily need, 5000 U.S.P. units; dose, 5000 to 25,000 units daily.
- Oleovitamin A and D, U.S.P.: In each gram between 850 and 1100 U.S.P. units of vitamin A and between 85 and 110 U.S.P. units of vitamin D. Dose, infants and adults, 8 cc. (2 fluidrachms) two or three times a day.
- Oleovitamin A and D, Concentrated, U.S.P.: In each gram 50,000 to 65,000 U.S.P. units of vitamin A and between 10,000 and 13,000 U.S.P. units of vitamin D. Dose, 0.1 cc. (2 drops) once or twice daily.
- Oleovitamin D, Synthetic, U.S.P. (Viosterol) (Activated Ergosterol) (Activated 7-dehydrocholesterol): Dose, 0.1 cc. (2 drops) one to three times a day.
- Opium, Powdered, U.S.P.: 0.06 gm. (1 grain) one or more times a day.
- Opium Tincture, U.S.P.: 0.6 cc. (10 minims) one or more times a day.
- Opium, Camphorated Tincture, U.S.P. (Paregoric): 4 cc. (1 fluidrachm) one or more times a day.
- Oridine, N.N.R. (23 per cent Iodine): 10 mg. (1/6 grain) three times a day.
- Ortal-Sodium, N.N.R.: Tablets, 50 mg., 0.2 gm., 0.3 gm., 3/4, 3 and 5 grains at bed time.
- Ouabain, U.S.P. (G. Strophanthin): I.V., I.M., dose, 0.25 to 0.5 mg. (1/250 to 1/120 grain).
- Ox Bile Extract, U.S.P.: 0.3 gm. (5 grains) three times a day.
- Oxyphenarsine Hydrochloride, U.S.P. (Mapharsen): I.V., 40 to 60 mg. (2/3 to 1 grain) every four or five days.
- Pancreatin, U.S.P.: 0.5 gm. (7 1/2 grains) three times a day.
- Pantothenic Acid: See *Calcium Pantothenate*.
- Papaverine Hydrochloride, U.S.P.: Oral or I.V., 0.03 gm. (1/2 grain) every three or four hours. Daily total, 0.5 gm. (7 1/2 grains).
- Para-aminobenzoic Acid (Paba): 0.1 to 0.5 gm. (1 1/2 to 7 1/2 grains) every three hours.
- Paraldehyde, U.S.P.: 4 cc. (1 fluidrachm). May be repeated every hour for several doses if necessary.
- Parathyroid, U.S.P. ("Paroidin"): 1 cc. has a potency of not less than 100 U.S.P. parathyroid units, each unit representing 1/100 of the amount necessary to raise the calcium content of 100 cc. of blood serum of normal dogs 1 mg. within sixteen to eighteen hours after administration. Dose, 20 to 40 units. Controlled by estimation daily of serum calcium.
- Penicillin Calcium, U.S.P.: Daily dose, oral 300,000 units on fasting stomach; intramuscular 300,000 units in divided doses, or intravenously continuously.
- Penicillin Sodium, U.S.P.: Daily dose, oral, 300,000 units on fasting stomach; intramuscular 300,000 units in divided doses, or intravenously continuously in solution of 25 to 50 units per cubic centimeter.
- Penicillin in Oil and Wax, U.S.P.: 300,000 units I.M. once daily in buttock muscles.
- Penicillin Tablets, U.S.P.: Oral, tablets, each 50,000 units every four hours.
- Pentaquine, N.N.R.: Oral, 60 mg. (1 grain) daily concurrently with quinine, 2 gm., in divided doses every four hours for fourteen days. To be used only in hospital environment.
- Pentnucleotide, N.N.R.: I.M., 8 per cent solution of sodium salts of 4 nucleotides prepared in 10 cc. vials. Dose, 1 vial four times daily into gluteal muscle.
- Pentobarbital Sodium, U.S.P. (Nembutal): Oral, rectal, I.V., 0.1 to 0.2 gm. (1 1/2 to 3 grains). Rectal, 30 mg. for infants; to 0.32 or 0.38 gm. for adults.
- Percomorph Liver Oil, N.N.R.: Per gram of vitamin A, 60,000 units, vitamin D, 8500 units. Dose, 10 to 20 drops daily.
- Pertussis Immune Serum, N.N.R.: Liquid or dried. Dried preparations: vial representing material in 20 cc. of serum to be dissolved in 10 cc. of water. Preventive I.V. or I.M., one vial repeated in three to five days. Therapeutic, 20 cc. at forty-eight hour intervals, three doses.
- Pertussis Hemophilus Vaccine, N.N.R.: Preventive, 15 billion per cubic centimeter, three injections, each 1 cc., at intervals of one week.
- Petrolagar, N.N.R.: Emulsion of liquid petrolatum with agar and either milk magnesia, calcium sacchara or phenolphthalein and one plain. Dose 1/2 to 1 tablespoonful one or more times daily night and morning.
- Petrolatum, Liquid, U.S.P.: Dose, 15 cc. (4 fluidrachms).

**edorn, N.N.R.** (Cyclobarbitol): Dose, 0.1 to 0.2 gm. ( $1\frac{1}{2}$  to 3 grains) at night.

**arsone Sulfoxylate, N.N.R.** (Aldarsone): I.V. (17 per cent arsenic), 1 gm. (15 grains) once weekly. For Trichomonas—insufflation of powder or insertion of suppository every two or three nights.

**etsal, N.N.R.** (51 per cent Salicylic Acid) (Salophen): 0.3 to 1 gm. (5 to 15 grains) three times daily.

**obarbital, U.S.P.** (Luminal): 15 mg. to 0.1 gm. ( $\frac{1}{4}$  to  $1\frac{1}{2}$  grains).

**obarbital Elixir, U.S.P.**: 4 cc. equals 15 mg. ( $\frac{1}{4}$  grain) three times daily.

**obarbital Sodium, U.S.P.**: In ampules, 2 cc.; each cubic centimeter equals 0.2 gm. (3 grains).

**olphthalein, U.S.P.**: 30 mg. to 0.2 gm. ( $\frac{1}{2}$  to 3 grains) at bed time.

**ostigmine Salicylate, U.S.P.**: Oral, 2 mg. ( $\frac{1}{30}$  grain); local eye use, 0.1 to 1 per cent solution.

**otoxin, U.S.P.**: I.V., 1 to 3 mg. ( $\frac{1}{60}$  to  $\frac{1}{20}$  grain), and repeat in one half to 1 hour, depending upon conditions.

**arpine Nitrate, U.S.P.**: 3 to 5 mg. ( $\frac{1}{20}$  to  $\frac{1}{12}$  grain) twice or three times a day.

**tary, Posterior, U.S.P.**: I.M., 10 U.S.P. units per cubic centimeter. Ampules, 0.5 and 1.0 cc. Dose, 3 to 10 units, repeated if necessary.

**Pitocin, N.N.R.**: I.M. (oxytocic), 10 U.S.P. units per cubic centimeter, 0.3 to 1.0 cc.

**Pitressin, N.N.R.**: I.M. (pressor, antidiuretic), 20 U.S.P. units per cubic centimeter, 0.3 to 1.0 cc.

**Pituitrin**: See *Pituitary, Posterior*.

**ue Vaccine, U.S.P.**: For active immunization. 2 billion organisms of *Bacillus pestis* per cubic centimeter. Doses, 0.5 cc., 1 cc. and 1 cc. at intervals of seven to ten days.

**tago Seed, N.N.R.** (Psyllium Seed): 4 to 15 gm. (1 to 3 drachms) per day.

**ma, Normal Human Citrated, U.S.P.**: Liquid, frozen or dried; I.V., 500 cc. (1 pint).

**ma, Normal Human Lyovac, N.N.R.**: I.V., 200 to 500 cc.

**ssium Acetate, U.S.P.**: 1 gm. (15 grains) three or more times per day.

**ssium Arsenite Solution, U.S.P.** (Fowler's): 0.2 cc. (3 minims) three times a day.

**ssium Bicarbonate, U.S.P.**: 1 gm. (15 grains) three times a day.

**ssium Bromide, U.S.P.**: 1 gm. (15 grains), repeat several times if needed.

**ssium Citrate, U.S.P.**: 1 gm. (15 grains) three times a day.

**ssium Iodide, U.S.P.**: 0.3 gm. (5 grains) three times daily.

**ssium Sodium Tartrate, U.S.P.** (Rochelle Salt): 10 gm. ( $2\frac{1}{2}$  drachms) once daily.

**esterone, U.S.P.** (Progestin, Proluton, Progesterone, Lutocytrin): I.M., 5 mg. ( $\frac{1}{12}$  grain) once daily.

**adrin Hydrochloride, N.N.R.**: Locally in 1 per cent solution; internally, 24 mg. ( $\frac{3}{8}$  grain) every two to four hours.

**stigmine**: See *Neostigmine*.

**lium Seed**: See *Plantago Seed*.

**thrum Ointment, N.N.R.**: 27 per cent extract. Local application for scabies.

**benzamine Hydrochloride**: 50 to 100 mg. ( $\frac{3}{4}$  to  $1\frac{1}{2}$  grains) four times daily.

**doxine Hydrochloride, N.N.R.** (Vitamin B<sub>6</sub>): 5 to 10 mg. ( $\frac{1}{12}$  to  $\frac{1}{6}$  grain) daily.

**iacrine Hydrochloride, U.S.P.** (Atabrine): Therapeutic, 0.1 gm. ( $1\frac{1}{2}$  grains) three or four times daily for nine or ten days. Suppressive, one dose of 0.1 gm. ( $1\frac{1}{2}$  grains) for two or three days each week.

**idine Sulfate, U.S.P.**: Test dose, 0.2 gm. (3 grains)—then 0.4 gm. (6 grains) three to five times daily.

**ine and Urethane Injection, U.S.P.**: Sclerosing agent, 2 cc. vials each with quinine hydrochloride, 250 mg. (4 grains) and urethane, 120 mg. (2 grains).

**ine Bisulfate, U.S.P.**: 1 gm. (15 grains) a day.

**ine Dihydrochloride, U.S.P.**: I.V., 0.25 gm., 0.5 gm., 1.0 gm. (4,  $7\frac{1}{2}$  and 15 grains) daily.

**ine Hydrochloride, U.S.P.**: Oral, 0.6 gm. (10 grains); I.M., 0.2 gm. (3 grains) three times a day.\*

**ine Sulfate, U.S.P.**: 0.6 gm. (10 grains) twice a day.

**es Vaccine, U.S.P.**: For active immunization. An uncontaminated suspension of the attenuated, diluted, dried or dead fixed virus of rabies obtained from brain or spinal cord of animals afflicted with rabies. The Pasteur preparation is best known, and consists of 21 doses, each on successive days. It is not always successful, and it may be followed by disturbances of the nervous system which are usually transient.

\* Several new synthetics promise better results than Quinacrine. They are chloroquine and drine, but are still in the process of marketing.

Resorcinol, U.S.P.: Solution 1 to 3 per cent; up to 10 per cent. Externally.

Riboflavin, U.S.P. (Vitamin B<sub>2</sub>): Oral, 1 to 5 mg. ( $\frac{1}{64}$  to  $\frac{1}{12}$  grain). Normal daily need, 3 mg.

Riodine, N.N.R. (Iodine, 17 per cent): 0.4 to 1.2 gm. (6 to 15 grains) per day.

Rice Polishings Extract, U.S.P.: Each cubic centimeter contains 20 U.S.P. units of vitamins and represents 14.5 gm. of rice polishings; 8 cc. (2 fluidrachms).

Saccharin, U.S.P.: 60 mg. (1 grain) equivalent sweetening power to 30 gm. of sucrose (1 ounce). Used in beverages or in cooking.

Saccharin Sodium, U.S.P.: 60 mg. (1 grain) equivalent sweetening power to 30 gm. (1 ounce) of sucrose.

Salvarsan: See *Arsphenamine*.

Salyrgan-Theophylline: See *Mersalyl*.

Scarlet Fever Immune Serum, Human, N.N.R. (Convalescent Serum): I.M., for passive immunity, 10 to 20 cc., according to age.

Scarlet Fever Streptococcus Antitoxin, U.S.P.: I.M., for passive immunity, 3000 units; for treatment, 9000 units. Each cubic centimeter must contain at least 400 U.S.P. H.S. and toxic units.

Scarlet Fever Streptococcus Toxin, U.S.P.: For Dick test and for active immunity. The amount of toxin needed varies with the individual—from 160 to 650 skin test doses for first dose. Dosage is then rapidly increased at weekly intervals until about 100,000 skin test doses are injected. The skin test dose is the smallest amount of toxin which, injected intracutaneously, will induce a reaction in any person susceptible to scarlet fever and negative reaction in any person immune.

Scarlet Fever Streptococcus Toxin, Tannic Acid Precipitated, N.N.R.: For active immunity, doses of 0.1 cc. intracutaneously at two week intervals in solutions of increasing skin test doses from 500 to 10,000.

Scillaren B, N.N.R.: I.V., 0.5 mg. in 1 cc. solution once in twenty-four hours.

Scillaren, N.N.R.: Oral, 0.8 to 1.6 mg. three or four times daily until minor toxic symptoms, then 0.8 mg. twice daily.

Scopolamine Hydrobromide, U.S.P. (Hyoscine Hydrobromide): 0.5 mg. ( $\frac{1}{120}$  grain), one dose.

Seconal Sodium, N.N.R.: 50 mg. to 0.1 gm. ( $\frac{3}{4}$  to  $1\frac{1}{2}$  grains).

Senna, U.S.P. (Senna Leaves or Powder): 2 gm. (30 grains) once daily.

Senna, Compound Powder (Compound Licorice Powder): 4 to 8 gm. (1 to 2 drachms) once daily.

Senna Syrup, U.S.P.: 8 cc. (2 fluidrachms) once daily.

Serum, Normal Human, U.S.P.: I.V., 500 cc. (1 pint).

Silver Nitrate, U.S.P.: Local in 1 per cent solution and stronger.

Silver Nitrate, Toughened, U.S.P.: 94.5 per cent AgNO<sub>3</sub>, in pencils or cones for local application.

Silver Protein, Mild, U.S.P. (Argyn, Neosilvol, Argylol): 19 to 23 per cent Ag. Freshly prepared 10 to 25 per cent solution for local use.

Silver Protein, Strong, U.S.P. (Protargol): 7.5 to 8.5 per cent Ag. Freshly prepared 0.5 to 2 per cent solution.

Siomine, N.N.R. (Methenamine Tetraiodide): 78.5 per cent iodine. Capsules, 60 mg., 0.13 gm., 0.3 gm. (1 to 5 grains) with meals.

Smallpox Vaccine, U.S.P.: In capillary glass tubes; for active immunization. "Multiple pressure method" of inoculation.

Sobisminol, N.N.R.: About 20 per cent bismuth. Oral, capsules, each 0.75 gm. (12 grains). Adult, 2 or 3 capsules three times daily. Solution: each cubic centimeter equals about 20 mg. of bismuth—2 cc. twice weekly.

Sodium Ascorbate: See *Ascorbic Acid*.

Sodium Bicarbonate, U.S.P.: 1 to 2 gm. (15 to 30 grains) at an interval after meals.

Sodium Biphosphate, U.S.P. (Sodium Acid Phosphate): 0.6 to 2 gm. (10 to 30 grains) three times a day.

Sodium Bromide, U.S.P.: 0.3 to 1 gm. (5 to 15 grains) two or three times daily.

Sodium Chloride, U.S.P.: Used by persons working in exceedingly hot places. Tablets, usually with dextrose, 0.5 gm. ( $7\frac{1}{2}$  grains) taken with drinking water.

Sodium Citrate, U.S.P.: 1 gm. (15 grains) three or more times daily.

Sodium Iodide, U.S.P.: 0.3 gm., oral (5 grains), three times daily; I.V., 1 or 2 gm. (15 to 30 grains) in 10 cc. of solution once daily.

Sodium Lactate, U.S.P.: I.V., 500 cc. and 1000 cc. bottles (1 and 2 pints).

Sodium Morrhuate Injection, U.S.P.: Sclerosing agent, 5 per cent solutions, 0.5 to 2 cc.

Sodium Nitrite, U.S.P.: 60 mg. (1 grain) every four hours.

- ium Perborate, U.S.P.: Local oral use only, in freshly prepared 2 per cent solution.
- ium Phosphate, U.S.P.: 4 to 8 gm. (1 or 2 drachms) once daily.
- ium Phosphate, Effervescent, U.S.P.: 10 gm. (2½ drachms), one dose.
- ium Salicylate, U.S.P.: 0.6 gm. (10 grains), up to 6 or 8 gm. (90 to 120 grains) per day.
- ium Sulfate, U.S.P. (Glauber's Salt): 4 to 15 gm. (1 to 4 drachms), one dose.
- ium Thiocyanate: 50 mg. to 0.3 gm. (1 to 5 grains) three times daily, with careful observation of blood cyanate level.
- ium Thiosulfate, U.S.P.: Oral, 1 gm. (15 grains) as cathartic; I.V. in dermatitis of arsphenamine, 1 gm. (15 grains) daily.
- phylococcus Antitoxin, N.N.R.: Subq. in local infections, 10,000 units. For severe infections, 30,000 to 100,000 units daily until recovery is evident. The unit is equivalent to 125 antidermonecrotic units, an antidermonecrotic unit being that amount of antitoxin required to neutralize one necrotizing dose of staphylococcus toxin.
- phylococcus Toxoid, N.N.R. (Anatoxin): Subq., initial dose is 0.1 cc. and contains 10 skin necrotizing doses. Subsequent doses at weekly intervals are increased by 10 or 20 skin necrotizing doses unless there is marked local or general reaction.
- phylococcus Toxoid Vaccine Mixture, N.N.R.: Each cubic centimeter contains 2 billion killed *Staphylococcus aureus* and the staphylococcus toxoid derived from 1000 necrotizing doses of toxin. Ten subcutaneous doses are given, the first 0.1 cc. and each dose thereafter increased by 0.1 cc. at weekly intervals unless a severe reaction follows.
- phylococcus Vaccine, N.N.R.: A bacterial vaccine made from the *Staphylococcus aureus*, *albus* and *citreus*. Each cubic centimeter to contain 1 to 2 billion organisms. Dosage, Subq., 100 million to 1000 million at three to five day intervals.
- bophen: See *Fuadin*.
- lbestrol: See *Diethylstilbestrol*.
- omach, Powdered, U.S.P. (Ventriculin): Oral, 1 U.S.P. unit daily.
- ovarsol: See *Acetarstone*.
- ramonium Extract, U.S.P. (Jimson Weed): 10 to 20 mg. (¼ to ⅓ grain) two or three times a day.
- ramonium Tincture, U.S.P.: 0.75 cc. (12 minims) two or three times a day.
- reptomycin, N.N.R.: I.V. drip, I.M., Subq., 1 to 4 gm. (15 to 60 grains) daily, in distilled water or isotonic salt solution.
- rophanthin: See *Oubain*.
- rophanthine Sulfate, U.S.P.: 1 to 2 mg. (1⁄60 to 1⁄30 grain) three or four times daily.
- uccinylsulfathiazole, U.S.P. (Sulfasuxidine): 1 gm. (15 grains) every four hours.
- ulphadital: Sulfathiazol, 37 per cent; sulfadiazine, 37 per cent; sulfamerazine, 26 per cent; 6 gm. per day, 1 gm. every four hours.
- ulfadiazine, U.S.P. } These drugs vary widely in absorption, elimination and in toxicity.
- ulfaguanidine, U.S.P. } They should be given with equal amounts of sodium bicarbonate and
- ulfamerazine, U.S.P. } with plenty of fluid. In the adult in severe infections the initial oral
- ulfanilamide, U.S.P. } dose is 2 to 4 gm., followed by 1 gm. doses every four hours day and
- ulfapyrazine, N.N.R. } night until the temperature is normal for three days. Dosage in chil-
- ulfapyridine, N.N.R. } dren is based upon body weight, 0.1 gm. per kilogram for the first
- ulfathiazole, U.S.P. } dose and one-quarter this each subsequent dose at six-hour intervals.
- ulfadiazine Sodium, U.S.P. } Given in 5 per cent watery solution intravenously in 2.5 to
- ulfamerazine Sodium, U.S.P. } 5 gm. initial dose in order to immediately raise the blood level
- ulfapyrazine Sodium, N.N.R. } of the drug to the effective range. Oral use should be started
- ulfapyradine Sodium, N.N.R. } soon as possible.
- ulfathiazole Sodium, U.S.P. }
- ulfarsphenamine, U.S.P. (19 per cent Arsenic): I.M. or I.V., 0.45 gm. (7 grains) once weekly.
- ulfonmethane, N.N.R. (Sulphonal): 0.6 gm. (10 grains) at night.
- ulfonethylmethane, N.N.R. (Trional): 0.6 gm. (10 grains) at night.
- uprarenalin: See *Epinephrine*.
- ramin Sodium, U.S.P. (Naphuride Sodium) (Bayer 205): I.V., 0.5 to 1.0 gm. (7½ to 15 grains) every two days. Watch for damage to suprarenals. Prophylaxis, 1 gm. (15 grains) every three or four months.
- ntropan, N.N.R.: 50 mg. (¾ grain) three or four times daily.
- annic Acid Glycerite, U.S.P. (20 per cent Tannic Acid in Glycerine): Local use, 0.5 to 2 per cent solutions.
- annic Acid Ointment, U.S.P.: Local use, 20 per cent.
- ar (Coal) Ointment, U.S.P. (Pix Carbonis): Local use, 5 per cent.

- Testosterone Propionate, U.S.P. (Anertan, Perandren, Oretone, Neohombreol, Testoviron): I.M., 5, 10, 25 mg. in 1 cc. of oil per week.
- Tetanus Antitoxin, U.S.P.: Passive immunization, 1500 units; therapeutic, 20,000 units and more. The unit (U.S.) is ten times the least amount of antitoxin which will save a 350 gm. guinea pig for ninety-six hours after subcutaneous injection of 100 M.L.D. of standard toxin. The minimum lethal dose (M.L.D.) is the smallest amount of freshly prepared toxin which, injected subcutaneously, will kill a 350 gm. guinea pig within ninety-six hours.
- Tetanus Antitoxin, Bovine, N.N.R.: Same standards and dosage, except that it is made from the serum of cattle, not horses.
- Tetanus Toxoid, U.S.P.: For active immunization, two doses, each 1.0 cc., are given subcutaneously at intervals of three months. It is the product of the growth of tetanus bacilli so modified as to have lost ability to cause toxic effects, but retaining the property of inducing active immunity. The toxicity is so low that 5 cc. injected subcutaneously will cause no symptoms in a guinea pig in twenty-one days. The antigenic value shall be such that 1 cc. injected subcutaneously shall six weeks after protect 80 per cent of guinea pigs for ten days against ten M.L.D. of tetanus test toxin.
- Tetanus Toxoid, Alum Precipitated, U.S.P.: For active immunization, doses, each 0.5 cc. or 1.0 cc., are given at intervals of three months.
- Tetanus and Gas Gangrene Antitoxin, U.S.P.: Passive immunization dose, 1 vial and up. Serum contains, per vial, 1500 units of tetanus antitoxin and 2000 units each of *Clostridium perfringens* and *Cl. septicum* antitoxin.
- Tetrachloroethylene, U.S.P. (Perchloroethylene): 1 to 3 cc. (15 to 45 minims), one dose, depending upon age, followed by a saline cathartic.
- Theelin: See *Estrone*.
- Theelol: See *Estriol*.
- Theobromine and Sodium Acetate, U.S.P.: 0.5 gm. (7½ grains) three or four times daily.
- Theocalcin, N.N.R.: 0.5 to 1 gm. (7½ to 15 grains) three times daily.
- Theophylline, U.S.P. (Theocin): 0.2 gm. (3 grains) three times daily.
- Theophylline and Sodium Acetate, U.S.P. (Theocin Soluble): 0.2 gm. (3 grains) three or four times daily.
- Theophylline Ethylenediamine: See *Aminophylline*.
- Thiamine Hydrochloride, U.S.P. (Vitamin B<sub>1</sub>): Oral, 10 to 100 mg. (¼ to 1½ grains) three times daily. Normal daily need, 2 mg. I.M., 25 to 100 mg. daily.
- Thiobismol, N.N.R.: I.M., 0.2 gm. (3 grains) three times weekly.
- Thiopental Sodium, U.S.P. (Pentothal Sodium) (for anesthesia): 2 to 3 cc. of 5 per cent solution repeated in two or three minutes if necessary.
- Thiouracil, N.N.R.: 0.4 gm. (6 grains) per day in divided doses.\*
- Thromboplastin, N.N.R.: For local application to bleeding surface.
- Thyloquinone: See *Menadione*.
- Thyroid, U.S.P.: 15 to 130 mg. (¼ to 2 grains) one or more times daily.
- Thyroxin, U.S.P.: I.V., 0.2 to 1 mg. (⅓<sub>20</sub> to ⅓<sub>60</sub> grain) daily.
- Totaquine, U.S.P.: 0.6 gm. (10 grains) three times a day.
- Triasyn B Tablets, U.S.P. (2 mg. of thiamine hydrochloride, 3 mg. of riboflavin, 20 mg. of nicotinamide): Tablet three times daily.
- Trichinella Extract, N.N.R.: For diagnosis, 0.1 cc. intradermally.
- Trimethadione, N.N.R. (Tridione): 0.3 gm. (5 grains) three to seven times daily.
- Trional: See *Sulfonethylmethane*.
- Tryparsamide, U.S.P.: I.V., 1 to 3 gm. (15 to 45 grains) once weekly.
- Tuberculin, Old, U.S.P.: Diagnostic, 0.00001 cc. to 0.001 cc. intracutaneously; therapeutic, 0.000,000,01 cc. to 0.000001 cc.
- Tuberculin, Purified Protein Derivative, U.S.P.: Diagnostic, 0.00002 mg. and 0.005 mg.
- Typhoid Vaccine, U.S.P.: Subq., for active immunization—doses, 0.5, 1.0 and 1.0 cc. at intervals of seven to ten days. It is a sterile suspension of killed typhoid bacilli in isotonic solution of sodium chloride in the strength of 1 billion organisms per cubic centimeter.
- Typhoid Combined Vaccine, U.S.P.: Subq., for active immunization—doses 0.5, 1.0 and 1.0 cc. at seven to ten day intervals. Combined vaccine is a suspension containing in each cubic centimeter of isotonic solution of sodium chloride 1 billion killed typhoid bacilli and 250 million each of paratyphoid A and paratyphoid B.
- Typhus, Epidemic Vaccine, U.S.P.: Subq., for active immunization—1 cc., to be repeated at seven to ten day intervals once or twice. Booster doses given at six months intervals for continued exposure. Made from rickettsia grown on yolk sac of embryo of domestic fowl.
- \* Propyl Thiouracil in the same dosage is less toxic.

thricin, N.N.R.: Local use in solution, 0.5 mg. per cubic centimeter.  
ulant Fever Vaccine: See *Brucella*.  
a, U.S.P. (Carbamide): 0.5 to 4 gm. daily.  
hane, U.S.P. (Ethyl Carbamate): 0.5 to 1.0 gm. 17 to 15 grains three times daily.  
nin, N.N.R. from Squill: 1 mg. (1/60 grain) is daily dose.  
ropin: See *Methenamine*.  
cines: See under name of disease.  
triculin: See *Stomach, Powdered*.  
onal: See *Barbital*.  
barbital Sodium, N.N.R. (Delvinal Sodium): 0.1 to 0.2 gm. (1 1/2 to 3 grains).  
sterol: See *Oleo Vitamins D Synthetic*.  
min D<sub>2</sub>, N.N.R. (Drisdol) (Calciferol): Solution in propylene glycol. Each cubic centimeter contains 0.25 mg. of drisdol and has a potency of 10,000 units of vitamin D (U.S.P.) per gram. Dose, 2 to 15 drops daily.  
min A: See *Burbot Liver Oil, Halibut Liver Oil, Halibut with Viosterol, Percomorph, Oleovitamin A, Oleovitamin A and D, Oleovitamin A and D Concentrated, Carotene and Carotene with Vitamin D*.  
min B: See *Calcium Pantothenate, Folic Acid, Nicotinic Acid, Pantothenic Acid, Para-aminobenzoic Acid, Pyridoxine, Riboflavin, Thiamine*.  
min C: See *Ascorbic Acid, Sodium Ascorbate*.  
min D: See *Burbot, Halibut and Percomorph Liver Oils, Oleovitamin A and D, Oleovitamin A and D Concentrated, Oleovitamin D Synthetic, Vitamin D<sub>2</sub> and Carotene with Vitamin D*.  
min K: See *Menadione*.  
min Mixed: See *Hexavitamin, Triacyn*.

TABLE 396

INTERNATIONAL STANDARDS

League of Nations Quarterly Bulletin of the Health Organization. Biological Standardization II  
November, 1936)

Substance	Nature of Preparation	International Unit (in Mg.)
ulin	Dry insulin hydrochloride (1925)	0.125
	Same (1935)	0.045
rus-producing hormones	{ Hydroxy-ketonic form (1932)	0.0001
	{ Benzoate of the dihydroxy form (1935)	0.0001
le hormone	Pure crystalline androsterone (1935)	0.1
pus luteum hormone	Pure crystalline progesterone (1935)	1.0

	<i>U.S.P.</i>	<i>N.N.R.</i>	<i>Speed</i>	<i>Du- ration</i>	<i>Tox- icity</i>	<i>Anesthe- tizing Power</i>	<i>Pene- tration M.M.</i>	<i>Irritation</i>	<i>Con- tion</i>
Alypin	—	+	±	±	66	100	Poor	Marked	
Amylsine hydrochloride, Amylcaine	—	+	+	+	Less	4 ×	Good	Slight	
Apothesine	—	+	Slow	Long	75	12	Poor	Moderate	
Butacaine sulfate (Butyn)	+	+	+	++	150	150	Good	Slight	No
Cocaine	+		+		100	100	Good	Slight	Con- str
Diothane hydrochloride	—	+		++	15	200	4 ×	Slight	
Eucaïne hydrochloride	+	—	Fair	Fair	20	50	Poor	Slight	N
Larocaine	—	+	+	++	45	200	Good		
Metycaine	—	+	+	+	$\frac{1}{3}$	200	Good		
Nupercaine, Dibucaine	—	+		++	500	2000	Good	Moderate	Rela
Phenacaine hydrochloride (Holocaine)	+	+	++	Short	150	150	Good		0
Procaine hydrochloride (Novocain)	+	+	+	Short	15	100	Poor	Slight	0
Tetracaine hydrochloride, Pantocaine	+	+	+	+	250	1500	Good		
Tutocaine hydrochloride (Butamin)	—	+	++	++	25	400	Good		

HETICS

<i>Eye</i>		<i>Infil- tration</i>	<i>Skin</i>	<i>Steril- ization</i>	<i>Solutions (per Cent)</i>				<i>May Add Epi- nephrine</i>
<i>Accom- modation</i>	<i>Tension</i>				<i>Eye</i>	<i>ENT</i>	<i>Infil- tration</i>	<i>Urethra</i>	
0	0	+	—	Boil	2-4	5-10	0.5-2	1-4	Yes
	0				2				
		Good		Boil	2	1-2	0.5-2		Yes
		Fair		Boil	2	2	0.1-0.4		
d Affected	Question	Fair	None	Boil		1-10	0.1-1		Yes
			As a cream		1	1	0.5		
0		Good		Boil	1-5	1-5	0.2		Yes
0		Fair		Boil	2-5	5-10	0.25-2	0.75-1	Yes
		Good	In oint- ment		2	2-10	0.5-1	1-4	Yes
		Good	Good		1:1000	4 in 1000	1:2000 (1:1000)		Yes
0	0	Toxic		Boil	1		Toxic		Yes
0	0	Good		Boil	1-5	5-20	0.25	0.1 in 10 cc.	Yes
				Boil	0.5	2			
		Good		Boil	1-2	2-5	0.2	0.5-1	Yes

## Chapter 73

### ISOTOPES

#### RADIOISOTOPES

RADIOISOTOPES, from irradiated units (as distributed by the Isotopes Branch, United States Atomic Energy Commission,\* are listed in alphabetical order in Table 398. An irradiated unit is a specified quantity of target material that has been sealed in an aluminum can and irradiated in the pile. The unit is removed from the pile and is shipped without chemical processing in a special container.

Radioisotopes are available for all elements (except oxygen and nitrogen) of value in biochemical work. They fall roughly into two categories: (a) those with weak radiation and (b) those with strong radiation. The weak group includes  $\text{H}^3$ ,  $\text{C}^{14}$ ,  $\text{S}^{35}$ ,  $\text{Ca}^{45}$ ,  $\text{Fe}^{59}$ ,  $\text{Co}^{60}$ . The strong group includes  $\text{C}^{11}$ ,  $\text{Na}^{24}$ ,  $\text{P}^{32}$ ,  $\text{K}^{42}$ ,  $\text{Co}^{56}$ ,  $\text{Cu}^{64}$ ,  $\text{Br}^{82}$ ,  $\text{I}^{131}$ .

#### CYCLOTRON-PRODUCED ISOTOPES

##### I. A cyclotron is the *only* source of:

1. *Any* reasonably long-lived radioisotope of *beryllium* ( $\text{Be}^7$ , half-life 43 days), *fluorine* ( $\text{F}^{18}$ , half-life 112 minutes), *vanadium* ( $\text{V}^{49}$ , half-life 600 days), *manganese* ( $\text{Mn}^{52}$ , half-life 6.5 days;  $\text{Mn}^{54}$ , half-life 310 days), *nickel* ( $\text{Ni}^{57}$ , half-life 36 hours), *xenon* ( $\text{Xe}^{127}$ , half-life 34 days), *lead* ( $\text{Pb}^{203}$ , half-life 52 hours), and *astatine* (85) ( $\text{At}^{211}$ , half-life 7.5 hours).

2. *Any* of the following important radioisotopes:  $\text{Na}^{22}$  (half-life 3 years) (pile makes only  $\text{Na}^{24}$ , with a half-life of 14.8 hours),  $\text{Fe}^{56}$  free of  $\text{Fe}^{59}$ ,  $\text{Fe}^{58}$  free of  $\text{Fe}^{55}$ ,  $\text{As}^{74}$  (half-life 16 days), arsenic (half-life 90 days) (pile makes only 27 hours and 40 hours isotopes), and krypton (half-life 34 hours). These can all be produced in the carrier-free state by the cyclotron.

3. *Any* of the following less important radioisotopes (since other reasonably long-lived radioisotopes of these elements are available from the pile):  $\text{Co}^{56}$ ,  $\text{Co}^{57}$ ,  $\text{Co}^{58}$ ,  $\text{Ag}^{106}$ ,  $\text{I}^{126}$ ,  $\text{I}^{130}$ ,  $\text{Re}^{184}$ ,  $\text{Au}^{196}$ ,  $\text{Ti}^{202}$ ,  $\text{Bi}^{207}$ .

II. A cyclotron is the only source of very high specific activity or carrier-free radioisotopes of beryllium, fluorine, vanadium, manganese, iron, cobalt, nickel, zinc, selenium, palladium, cadmium, xenon, rhenium, mercury, thallium, lead, bismuth, astatine (85).

\* Data from Catalog No. 2, revised September, 1947, Oak Ridge, Tennessee.

TABLE 398  
IRRADIATED UNITS

Radioisotopes in Unit		See also No.	Half-Life	Radiation (Mev)		Estimated Quantity (Mc)	Mc/g Element (Est.)
Mathematical List	Others Present			Beta	Gamma		
Antimony 122	Sb <sup>124</sup>	2	2.8 d 60 d	1.36, 1.94 0.53, 2.25	0.57 1.72	50 1	250 5
Antimony 124	Sb <sup>122</sup>	1	60 d 2.8 d	0.53, 2.25 1.36, 1.94	1.72 0.57	4 55	20 275
Antimony 125	Sn <sup>113</sup> Sn <sup>121</sup> Sn <sup>123</sup> Sn <sup>125</sup> (parent of Sb <sup>125</sup> )		2.7 y 100 d 62 h 10 d 9 m	0.8, 0.3 K, e <sup>-</sup> 0.8 2.6 ~2.2	Present 0.085 None Present ~0.74	1.0 1.0 ? ? ?	C.F. 0.16 ? ? ?
Argon 37		13					
Arsenic 76			26.8 h	1.1, 1.7, 2.7	0.57, 1.25	25.0	560
Arsenic 77	Ge <sup>71</sup> Ge <sup>77</sup> (parent of As <sup>77</sup> )		40 h { 11 d 40 h 12 h	0.8 { 0.6 B <sup>+</sup> 1.2 B <sup>+</sup> 1.9	None 0.6	0.70 10 0.7	C.F. 10 0.7
Barium 131 (parent of Cs <sup>131</sup> )	Cs <sup>131</sup> C <sup>14</sup>		12 d 10.2 d 5100 y	K, e <sup>-</sup> K 0.154	1.2 (weak) None None	6.0 9.0 0.02	0.26 C.F. C.F.
Barium 140 (fission prod- uct)	La <sup>140</sup> (daugh- ter)		12.8 d	1.05	0.542		
Bismuth 210	Po <sup>210</sup>		5 d 140 d	1.17 5.298 a, e <sup>-</sup>	None 0.8 (weak)	10 0.3*	0.4 C.F.
Bromine 82	K <sup>42</sup>		34 h 12.4 h	0.465 { 3.58 (75%) 2.07 (25%)	{ 0.547, 0.787, 1.35 1.51 (25%)	70 3	120 10
Cadmium 115	Cd <sup>109</sup> Cd <sup>115</sup>	12	2.33 d 300 d 43 d	1.13, 0.6 K 1.85	0.65 None ~0.5	20 - 0.25	20 - 0.25
Cadmium 115	Cd <sup>109</sup> Cd <sup>115</sup>	11	43 d 300 d 2.33 d	1.85 K 1.13, 0.6	~0.5 None 0.65	1 - 20	1 - 20
Calcium 45	A <sup>37</sup>	72	180 d 34 d	0.250 K	None None	0.8 0.2	0.1 C.F.
Carbon 14	(Also available in separated form)	7	5100 y	0.150	None		C.F.
Cerium 141			28 d 33 h 13.8 d	0.55 1.35 0.95	0.21 0.5 None	50 12 3	75 18 C.F.
Cerium 143		15					
Cerium 144 (fission product)	Ce <sup>143</sup> Pr <sup>144</sup>		275 d	0.348	None		
Cesium 131 (daughter of Ba <sup>131</sup> )	Ba <sup>131</sup> C <sup>14</sup>	7					

Maximum quantity 25 days after removal from pile.

Half-Life: y = years, d = days, h = hours, m = minutes, s = seconds.

C.F. means "Carrier Free."

Mev means energy of the radiation in terms of millions of electron volts.

Mc is radioactivity in millicuries.

Mc/g is millicuries per gram of the element which has been made radioactive.

K is internal conversion electrons.

T. is isomeric transition

TABLE 398—Continued

No.	Radioisotopes in Unit		See also No.	Half-Life	Radiation (Mev)		Estimated Quantity Me	Meq. H. L. per 100 g.
	Alphabetical List	Others Present			Beta	Gamma		
19	Cesium 134			2 y	0.645	{ 0.584, 0.776 (95%) 1.35 (5%)	20	40
20	Cesium 137 (fission product)			33 y	0.84 (50%)  0.5 (50%)	0.75		
21	Chlorine 36	K <sup>42</sup>  S <sup>35</sup> P <sup>32</sup>		10 <sup>6</sup> y 12.4 h  87.1 d 14.3 d	0.66 { 3.58 (75%) 2.07 (25%) 0.17 1.69	None 1.51 (25%)  None None	0.005 200  100 0.01	0.005 15  C.F. C.F.
22	Chromium 51			26.5 d	K	0.32	50	50
23	Cobalt 60			5.3 y	0.3	1.1, 1.3	20	30
24	Columbium (fission product)	Zr <sup>95</sup>		35 d	0.15	0.75		
25	Copper 64			12.8 h	{ 0.58 B <sup>-</sup> 0.66 B <sup>+</sup> K	  1.2 (weak)	100	300
26	Europium 154	Eu <sup>152</sup>		5-8 y  9.2 h	{ 0.34 (50%) 0.82 (50%) 1.61	1.4 et al	40 ***	180
27	Europium 155 (fission product)	Illinium 147 Eu <sup>156</sup>	71	2 y	0.3	0.084		
28	Europium 156 (fission product)	Illinium 147 Eu <sup>155</sup>		15.4 d	0.5 (60%)  2.5 (40%)	2.0		
29	Gallium 72			14.1 h	3.1, 0.8	0.84, 2.25	25	170
30	Germanium 71		6					10
31	Germanium 77		6					
32	Gold 198			2.7 d	0.97	0.44	80	5000
33	Gold 199	Pt <sup>197</sup> Pt <sup>199</sup> (parent of Au <sup>199</sup> )		3.3 d 18 h, 3.3 d 31 m	1.01 0.72 1.8	0.45 Present	10 7	C.F. 14
34	Hafnium 181			46 d	0.8	0.5	50	60
35	Illinium 147	Il <sup>149</sup> Nd <sup>147</sup> Nd <sup>149</sup> (parent of Il <sup>149</sup> )		3.7 y 2 d 11 d 47 h	0.233 ? ~0.4 (40%) 0.90 (60%) 0.78, 1.2	None ? 0.55 0.25	0.001 0.1 0.03 ?	C.F. C.F. 3.5
36	Illinium 149		35					
37	Indium 114			48 d 72 s	{ I.T., e <sup>-</sup> 1.95	0.19	10	70
38	Iodine 131	Te <sup>127</sup>   Te <sup>129</sup> Te <sup>131</sup> (parent of I <sup>131</sup> )		8 d 90 d  9.3 h 32 d 70 m 30 h 25 m	0.6 I.T., e <sup>-</sup>  0.70 { I.T., e <sup>-</sup> 1.8 I.T., e <sup>-</sup> Present	0.367, 0.080 0.055, 0.082, { 0.085 X-ray: 0.028 None { 0.102, X-ray 0.3, 0.8 0.177	10   8 10	C.F. 0.20  0.16 0.20

\*\*\* Item 26 will not be shipped until Eu 152 activity has decayed to a very low level.

TABLE 398—Continued

Radioisotopes in Unit		See also No.	Half-Life	Radiation (Me)		Estimated Quantity (Mc)	Mc/g Element (Est.)
Alphabetical List	Others Present			Beta	Gamma		
Iodine 131 (Separated form)			8 d	0.6	0.367, 0.080		C.F.
Iridium 192	Ir <sup>194</sup>	41	75 d 19 h	0.59 2.07	0.2–0.6 complex 0.38, 1.65	40 200	210 1050
Iridium 194	Ir <sup>192</sup>	40	19 h 75 d	2.07 0.59	0.38, 1.65 0.2–0.6 complex	40 3	930 70
Iron 55		43					
Iron 59	Fe <sup>55</sup>		44 d 4 y	0.26, 0.46 K	1.1, 1.3 0.07	1.0 0.9	0.06 0.05
Lanthanum 140			40 h	0.9 (20%) {1.40 (70%) 2.12 (10%)}	1.65 complex	40	525
Mercury 197	Hg <sup>203, 205</sup>	46	{64 h 25 h 51.5 d	{K, e <sup>-</sup> K, e <sup>-</sup> 0.3	0.075 0.13, 0.16 0.28	95 40	8 3
Mercury 203, 205	Hg <sup>197</sup>	45	51.5 d {64 h 25 h	0.3 {K, e <sup>-</sup> K, e <sup>-</sup>	0.28 0.075 0.13, 0.16	135 110	11 9
Molybdenum 99 (parent of Tc <sup>99</sup> )	Tc <sup>99</sup>	83	67 h 10 <sup>6</sup> y	1.3 0.3	0.770, 0.815 0.840 None	40 Very small	10 C.F.
Neodymium 147 (fission product)	Pr <sup>143</sup>	35	11 d	0.4 (40%) 0.9 (60%)	0.55		
Neodymium 149		35					
Nickel 59			15 y	K, e <sup>-</sup>		1	0.1
Osmium 185		53					
Osmium 191		53					
Osmium 193	Os <sup>185</sup> Os <sup>191</sup>		17 d 80 d 32 h	0.35 K 1.5	Present None 1.17	40 ? 18	73 33
Palladium 103	Ag <sup>111</sup> Rh <sup>103</sup>	75	17 d 7.5 d 5.6 m	K 1.0 I.T.	None None 0.40	Undeter- mined 10	C.F.
Phosphorus 32	S <sup>35</sup>	21, 56, 79	14.3 d 87.1 d	1.69 0.17	None None	1500 80	C.F. 0.04
Phosphorus 32	K <sup>42</sup>	21, 55, 79	14.3 d 12.4 h	1.69 {3.58 (75%) 2.07 (25%)}	None 1.51 (25%)	350 140	50 15.7
Phosphorus 32	(Also avail- able in sep- arated form)		14.3 d	1.69	None		(0.5 to 3.0 mc per ml.)
Platinum 197	Au <sup>199</sup> Pt <sup>199</sup>	33					
Platinum 199	Au <sup>199</sup> Pt <sup>197</sup>	33					

TABLE 398—Continued

No.	Radioisotopes in Unit		See also No.	Half-Life	Radiation (Mev)		Estimated Quantity (Mc)	Meq/L or g/L
	Alphabetical List	Others Present			Beta	Gamma		
60	Polonium 210	Bi	9					
61	Potassium 42		10, 21, 56	12.4 h	{ 3.58 (75%) 2.07 (25%)	1.51 (25%)	130	10
62	Praseodymium 142			19.3 h	2.14	1.9	40	500
63	Praseodymium 143		15					
64	Rhenium 186	Re <sup>188</sup>		90 h 18 h	1.0 2.05	None 0.16–1.45 Complex	75 120	1,500 2400
65	Rhenium 188		64					
66	Rhodium 105	Tc <sup>97</sup> Ru <sup>97</sup> (parent of Tc <sup>97</sup> ) Ru <sup>103</sup>	68	36 h 93 d 2.8 d 42 d	0.5 K, e <sup>-</sup> K, e <sup>-</sup> { 0.2 (95%) 0.8 (5%)	0.3 0.97 0.22, 0.18 0.56	10 0.3 8 3	C.F. C.F. 2 1
67	Rubidium 86			19.5 d	1.60	None	100	20
68	Ruthenium 97	Tc <sup>97</sup> Ru <sup>103</sup> Rh <sup>105</sup>	66	2.8 d 93 d 42 d 36 h	K, e <sup>-</sup> K, e <sup>-</sup> { 0.2 (95%) 0.8 (5%) 0.5	0.22, 0.18 0.97 0.56 0.3	10 1 10 10	3 C.F. 3 C.F.
69	Ruthenium 103	Rh <sup>106</sup> (daugh- ter)	66, 68, 88	42 d	0.2 (95%) 0.8 (5%)	0.56		
70	Ruthenium 106 (fission product)	Rh <sup>106</sup> Te <sup>127</sup> Te <sup>129</sup>		1 y	Very soft	None		
71	Samarium 153	Eu <sup>155</sup> Sm <sup>155</sup> (parent of Eu <sup>155</sup> )		47 h 2 y 25 m	0.73 0.3 1.9	0.1, 0.57 (weak) 0.084 ~0.3	16 0.01	2000 C.F.
72	Scandium 46	Ca <sup>46</sup>		85 d 180 d	0.36 0.250	1.12, 0.90 None	15 0.001	750 C.F.
73	Selenium 75			125 d	K, e <sup>-</sup>	<0.3 complex 0.5	65	3.3
74	Silver 110			225 d	0.59	0.66 (44%) 0.90 (47%) 1.40 (9%)	35	8
75	Silver 111	Pd <sup>103</sup>	54	7.5 d 17 d	1.0 K	None None	10 ?	C.F. ?
76	Sodium 24			14.8 h	1.4	1.4, 2.8	20	150
77	Strontium 89			55 d	1.5	None	1.5	0.11
78	Strontium 90 (fission product)	Sr <sup>89</sup> Y <sup>90</sup>		25 y	0.65	None		
79	Sulfur 35	P <sup>32</sup>	21, 55	87.1 d 14.3 d	0.17 1.69	None None	1.0 6.0	0.04 C.F.
80	Sulfur 35 (also avail- able in sep- arated form)			87.1 d	0.17	None	~1.53 mc per ml	

TABLE 398—Continued

Radioisotopes in Unit		See also No.	Half-Life	Radiation (Mev)		Estimated Quantity (Mc)	Mc/g Element (Est.)
Alphabetical List	Others Present			Beta	Gamma		
Tantalum 182			117 d	0.53	1.13, 1.22 <1.0 complex	40	215
Technetium 97		66, 68	93 d				
Technetium 99	Mo <sup>99</sup>	47	10 <sup>6</sup> y 67 h	0.3 1.3	None {0.770, 0.815 0.840	0.00001 45	C.F. 11
Tellurium 127 (fission product)	Ru <sup>103</sup> Ru <sup>106</sup> Te <sup>129</sup>	38	90 d 9.3 h	I.T., e <sup>-</sup> 0.70	0.055, 0.082, 0.085 None		0.2
Tellurium 129 (fission product)	Ru <sup>103</sup> Ru <sup>106</sup> Te <sup>127</sup>	38	32 d 70 m	I.T., e <sup>-</sup> 1.8	0.102 0.3, 0.8		0.16
Tellurium 131		38	30 h 25 m	I.T., e <sup>-</sup> Present	0.177		0.20
Thallium 204			2.7 y	0.58	None	7	1.2
Tin 113		3					
Tin 121		3					
Tin 123		3					
Titanium 51	Sc <sup>46</sup> 47, 48 prob- able		72 d	0.36	1.0	1	0.09
Tungsten 185	W <sup>187</sup>	93	77 d 24 h	0.7 0.6, 1.3	None {0.086-0.94 complex	10 500	7 350
Tungsten 187	W <sup>185</sup>	92	24 h 77 d	0.6, 1.3 0.7	0.086-0.94 complex None	40 0.2	420 2.1
Yttrium 90			62 h	2.16	None	100	115
Yttrium 91			57 d	1.53	None		
Zinc 65	Zn <sup>69</sup>		250 d {13.8 h 59 m	{0.4 B <sup>+</sup> (1%) K, e <sup>-</sup> (99%) I.T. 1.0	1.14 0.439	15 60	1.9 7.5
Zinc 69		96					
Zirconium 95			65 d	{1.0 (2%) 0.394 (98%)	0.73 0.92	12	9.5

STABLE ISOTOPES

The only practical method of measuring stable isotopes (with the possible exception of deuterium) is the mass spectrometer. The ratio of abundance can be determined down to a probable error of 1 per cent to 0.2 per cent, depending on the element and the absolute value. The measurements consist in determining the ratio of abundance of the element in question. The ratio is conveniently expressed as "atom per cent." Thus, if there were 1.1 atoms of  $C^{13}$  out of every 100 atoms of  $C^{12}$ , the ratio would be 1.1 atoms per cent. The expression "atom per cent excess" is convenient in the calculation of dilutions. If an enriched sample contains 3 atoms per cent  $C^{13}$ , then the atom per cent excess is obtained by subtracting the normal abundance. Thus  $3 - 1.1$  equals 1.9 atoms per cent  $C^{13}$  excess.

The sensitivity of isotope concentration measurements depends on the type and design of the instrument used and upon the abundance of the stable isotopes existing in nature. The latter acts as a contaminant in the determination. Table 399 shows the stable isotopes existing in nature.

TABLE 399  
STABLE ISOTOPES EXISTING IN NATURE\*

<i>Element</i>	<i>Isotope Masses</i>	<i>Abundance Ratios</i>
H.....	1:2	99.98:0.02
B.....	10:11	18.4:81.6
C.....	12:13	98.9:1.1
N.....	14:15	99.62:0.38
O.....	16:17:18	99.76:0.041:0.20
S.....	32:33:34	95.1:0.74:4.2
Ca.....	40	96.96
	42	0.64
	43	0.15
	44	2.06
	46	0.0033
Fe.....	48	0.19
	54	6.04
	56	91.57
	57	2.11
	58	0.28

\* Nucleonics, 1:25, 1947.

## THE ELECTROMAGNETIC SPECTRUM

The properties of the radiations in the electromagnetic spectrum depend on their wavelengths. The units commonly employed for specifying wavelengths are the angstrom ( $\text{\AA}$ ) and the millimicron ( $\text{mu}$ ). The angstrom is equal to one ten-millionth of a millimeter ( $10^{-7}$  mm.), and the millimicron is equal to one millionth of a millimeter ( $10^{-6}$  mm.;  $1 \text{ mu} = 10 \text{ \AA}$ ).

The electromagnetic spectrum may be qualitatively divided into the categories shown in Table 400.

TABLE 400

THE ELECTROMAGNETIC SPECTRUM

	Wavelength		
	Angstroms	Millimicrons	Meters
gamma rays, from radium series . . . . .	0.0056-1.37		
x-rays . . . . .	0.0001-5.0		
ultraviolet rays: Far . . . . .	100-2900		
Near . . . . .	2900-4000	290-400	
visible rays: Violet . . . . .	400-450		
Blue . . . . .	450-490		
Green . . . . .	490-550		
Yellow . . . . .	550-590		
Orange . . . . .	590-630		
Red . . . . .	630-750		
infrared rays: Near . . . . .	750-1400		
Far . . . . .	1400-200,000		
radio waves (radar, radio, etc.) . . . . .			0.0002-30,000

TABLE 401

## TABLE OF INTERNATIONAL ATOMIC WEIGHTS\*

Name	Symbol	Atomic Number	Atomic Weight	Valence
Actinium.....	Ac	89	(227)	
Alabamine (?).....	Ab	85	(221)	1, 3, 5, 7
Aluminum.....	Al	13	26.97	3
Antimony, stibium.....	Sb	51	121.76	3, 5
Argon.....	A	18	39.944	0
Arsenic.....	As	33	74.91	3, 5
Barium.....	Ba	56	137.36	2
Beryllium, glucinum.....	Be	4	9.02	2
Bismuth.....	Bi	83	209.00	3, 5
Boron.....	B	5	10.82	3
Bromine.....	Br	35	79.916	1, 3, 5, 7
Cadmium.....	Cd	48	112.41	2
Calcium.....	Ca	20	40.08	2
Carbon.....	C	6	12.01	2, 4
Cassiopeium. See <i>Lutecium</i> .				
Cerium.....	Ce	58	140.13	3, 4
Cesium.....	Cs	55	132.91	1
Chlorine.....	Cl	17	35.457	1, 3, 5, 7
Chromium.....	Cr	24	52.01	2, 3, 6
Cobalt.....	Co	27	58.94	2, 3
Columbium, niobium.....	Cb	41	92.91	3, 5
Copper.....	Cu	29	63.54	1, 2
Dysprosium.....	Dy	66	162.46	3
Erbium.....	Er	68	167.2	3
Europium.....	Eu	63	152.0	2, 3
Fluorine.....	F	9	19.00	1
Gadolinium.....	Gd	64	156.9	3
Gallium.....	Ga	31	69.72	2, 3
Germanium.....	Ge	32	72.60	4
Gold, aurum.....	Au	79	197.2	1, 3
Hafnium, celtium.....	Hf	72	178.6	4
Helium.....	He	2	4.003	0
Holmium.....	Ho	67	164.94	3
Hydrogen.....	H	1	1.0080	1
Illinium.....	Il	61	(146)	(3)
Indium.....	In	49	114.76	3
Iodine.....	I	53	126.92	1, 3, 5, 7
Iridium.....	Ir	77	193.1	3, 4
Iron, ferrum.....	Fe	26	55.85	2, 3
Krypton.....	Kr	36	83.7	0
Lanthanum.....	La	57	138.92	3
Lead, plumbum.....	Pb	82	207.21	2, 4
Lithium.....	Li	3	6.940	1
Lutecium.....	Lu	71	174.99	3
Magnesium.....	Mg	12	24.32	2
Manganese.....	Mn	25	54.93	2, 3, 4, 6, 7
Masurium.....	Ma	43		
Mercury, hydrargyrum.....	Hg	80	200.61	1, 2
Molybdenum.....	Mo	42	95.95	3, 4, 6

\* From 13th Report of Committee on Atomic Weights of the International Union of Pure and Applied Chemistry (J. Am. Chem. Soc., 69:73, 1947). Values in parentheses are approximate only and have not been adopted by the Committee.

TABLE 401—Continued

<i>Name</i>	<i>Symbol</i>	<i>Atomic Number</i>	<i>Atomic Weight</i>	<i>Valence</i>
mium.....	Nd	60	144.27	3
.....	Ne	10	20.183	0
.....	Ni	28	58.69	2, 3
See Radon.				
gen.....	N	7	14.008	3, 5
um.....	Os	76	190.2	2, 3, 4, 8
n.....	O	8	16.0000	2
lium.....	Pd	46	106.7	2, 4
phorus.....	P	15	30.98	3, 5
um.....	Pt	78	195.23	2, 4
ium.....	Po	84	(210)	
sium, kalium.....	K	19	39.096	1
odymium.....	Pr	59	140.92	3
ctinium.....	Pa	91	231	
um.....	Ra	88	226.05	2
n, niton.....	Rn	86	222	0
ium.....	Re	75	186.31	
ium.....	Rh	45	102.91	3
dium.....	Rb	37	85.48	1
enium.....	Ru	44	101.7	3, 4, 6, 8
rium.....	Sm, Sa	62	150.43	3
dium.....	Sc	21	45.10	3
ium.....	Se	34	78.96	2, 4, 6
n.....	Si	14	28.06	4
r, argentum.....	Ag	47	107.880	1
um, natrium.....	Na	11	22.997	1
itium.....	Sr	38	87.63	2
r.....	S	16	32.066	2, 4, 6
alum.....	Ta	73	180.88	5
rium.....	Te	52	127.61	2, 4, 6
ium.....	Tb	65	159.2	3
lium.....	Tl	81	204.39	1, 3
ium.....	Th	90	232.12	4
ium.....	Tm	69	169.4	3
stannum.....	Sn	50	118.70	2, 4
nium.....	Ti	22	47.90	3, 4
gsten, wolframium.....	W	74	183.92	6
ium.....	U	92	238.07	4, 6
adium.....	V	23	50.95	3, 5
inium (?).....	Vi	87	(224)	1
on.....	Xe	54	131.3	0
rbium.....	Yb	70	173.04	3
ium.....	Y	39	88.92	3
.....	Zn	30	65.38	2
onium.....	Zr	40	91.22	4

## RADIUM IN THE BODY

Hursh and Gates measured the content of radium in the bodies of persons who had had no known exposure to this element. Their data are given in Table 402. The first five results in the table are regarded as erroneously high, owing to contamination during ashing. The average of the last fifteen measurements is  $1 \times 10^{-10}$  grams of radium, which these workers regard as a reliable average value.\*

TABLE 402

RADIUM BODY CONTENT OF OCCUPATIONALLY UNEXPOSED PERSONS\*  
(Data of Hursh and Gates)

Subject	Age in Years	Sex	Occup.	Birth- place	Resi- dence in N.Y.S. Years	Total Ash (Gm.)	Ali- quot Meas. (Gm.)	Activity of Ali- quot 10 <sup>-12</sup> cu. Rn	Ra Con- tent per gm. 10 <sup>-12</sup> g Ra	Ra Con- tent Whole Body 10 <sup>-12</sup> Rn
B. T.	82	M	Printer	New York	82	2580	25.8	3.6	1.7	4.3
E. H.	55	M	Cook	Vermont	40†	2500‡	25.0	2.2	1.3	3.3
J. H.	68	M	None	Austria	50†	2500‡	20.3	0.9	0.5	1.2
A. B.	54	M	Laborer	Canada	40†	2500‡	25.0	3.4	1.7	4.3
F. T.	65	M	Odd jobs	New York	65	3350	33.5	6.5	2.5	8.4
W. M.	48	M	Odd jobs	South Carolina	35†	4410	22.0	1.5	0.8	3.5
R. P.	85	F	None	U. S. A.	60	1500	15.0	1.2	0.9	1.4
M. B.	60	M	....	....	40†	2500	20.0	0.6	0.3	0.8
J. C.	57	M	....	....	..	2100	21.0	1.4	0.8	1.6
W. B.	77	M	Painter	New York	77	1700	20.0	0.6	0.3	0.5
E. G.	76	M	Decorator	England	50†	2000	20.0	0.7	0.4	0.7
J. D.	83	M	....	Pa.	60†	2200	20.0	0.7	0.3	0.6
M. L.	77	F	Housewife	U. S. A.	55†	790	20.0	0.7	0.4	0.3
J. W. H.	36	M	Odd jobs	Alabama	25†	2480	20.0	0.5	0.2	0.6
D. P.	74	M	Mason	New York	74	2260	20.0	0.7	0.4	0.8
G. D.	81	M	Laborer	New York	81	1570	20.0	1.4	0.8	1.2
J. O.	66	M	Machinist	New York	66	1970	20.0	0.7	0.4	0.7
J. S.	85	M	....	....	..	2570	20.0	0.7	0.4	0.9
C. D.	75	M	Carpenter	Canada	50	2000	20.0	0.6	0.3	0.5
H. R.	74	M	Laborer	Germany	35	2310	20.0	0.8	0.3	0.9

\* Personal communication, J. B. Hursh and O. A. Gates, Rochester, N. Y.

† Estimated years of residence in New York state.

‡ Estimated total ash weights.

Note 1. The values in the last 2 columns have been corrected for radium recovery and radium content of reagents used for digestion.

Note 2. The first 5 bodies were ashed on the floor of the crematorium and may have been contaminated with fire brick dust and cement. Subsequently bodies were ashed on a stainless steel platform largely avoiding such contamination.

\* Personal communication of John B. Hursh.

## GLOSSARY OF SOME TERMS USED IN ISOTOPE RESEARCH

**Symbol for Mass Number.**

**$\alpha$  particle.** The nucleus of a helium atom, having a double positive charge. It consists of two protons and two neutrons, atomic number 2, mass number 4.

**Atom.** The smallest unit of matter remaining unchanged in chemical reactions. Atoms are about  $10^{-8}$  cm. in diameter. They consist of a central positively charged nucleus, about  $10^{-14}$  cm. in diameter, surrounded by enough electrons to make the atom electrically neutral. The number of positive charges on the nucleus (atomic number) and thus the number of electrons around the nucleus, determine the properties of the atom.

**Atom per cent.** The ratio in per cent of the number of atoms of one isotope of an element to the number of atoms of another isotope of the same element. For example, the ratio of  $C^{13}$  to  $C^{12}$  in nature is 1.1 to 98.9, or 1.1 out of every 100 atoms is  $C^{13}$ . The ratio is 1.1 atoms per cent.

**Atom per cent excess.** A method of indicating how much a sample is enriched in an isotope. Thus, if an enriched sample contains 2.51 atoms per cent  $C^{13}$ , the atom per cent excess is calculated by subtracting the normal abundance (1.1 atoms per cent), which gives 1.41 atoms per cent excess. The method makes calculations of dilutions easier.

**Atomic number.** The number of an element when arranged with others in order of increasing atomic weight. It is characteristic of an element and is equal to the number of positive charges in the nucleus, and thus to the number of orbital electrons in the normal atom. Symbol is  $Z$ . Thus for hydrogen  $Z = 1$ , for helium  $Z = 2$ , for uranium  $Z = 92$ .

**Atomic weight.** The relative weight of an atom referred to oxygen as 16.000. See *Mass number*.

**Beta ray.** Beta rays consist of negative electrons emitted by an atom in the process of radioactive disintegration. These electrons are emitted with energies which vary between wide limits, from low values which are difficult to measure, to values of several million electron volts. The velocities attained by the highest energy beta rays approach that of light. Symbol is  $B^-$ .

**Symbol for the velocity of light**  $= 3 \times 10^{10}$  cm. per second.

**Chain reaction.** Any reaction which continues by virtue of the action of one of the products to cause the reaction to continue. For example, uranium fission results from the absorption of a neutron by the nucleus. When the fission takes place, more neutrons are released which can cause more fissions.

**Carrier.** A nonradioactive isotope of the element in question.

**Curie.** A curie originally was the amount of radioactive products in equilibrium with 1 gm. of radium. Since the discovery of artificial radioactivity it has been defined as that amount of the isotope necessary to provide  $3.7 \times 10^{10}$  disintegrating atoms per second. The millicurie is one thousandth of a curie.

**Half-life.** The decrease with the passage of time in the number of radioactive atoms originally present, due to their disintegration.

**Deuteron.** The nucleus of the atom of heavy hydrogen; the simplest composite nucleus, consisting of one proton and one neutron:  $Z = 1$ ,  $A = 2$ .

**Disintegration.** The spontaneous transformation of one atom into another by a radioactive change occurring in the nucleus. Disintegration may be brought about by bombardment of nuclei with subatomic particles (induced radioactivity).

**Disintegration constant.** The rate of radioactive disintegration. It is the proportion of radioactive atoms present that disintegrate in unit time. The amount of any radioactive substance  $Q$ , that will be present at any time  $t$ , can be calculated from the amount on hand ( $Q_0$ ) by the formula:

$$Q = Q_0 e^{-\lambda t}$$

$e$  is a constant, the base of natural logarithms, and  $\lambda$  the disintegration constant in terms of the time unit used for  $t$ .

**Electron.** The smallest atomic particle; an elementary particle of negative electricity. Its charge is equal to  $4.77 \times 10^{-10}$  electrostatic units, or  $1.60 \times 10^{-19}$  coulomb; its mass at rest, about  $9 \times 10^{-28}$  gm. The equal and opposite charge is the positron, sometimes called a positive electron. Symbol:  $e^-$ ,  $e^+$ , respectively.

**Electron volt.** The energy required to move a unit electronic charge through a potential difference of one volt ( $1.602 \times 10^{-12}$  ergs). Symbol, "ev."

**Energy equivalence of mass.** A given mass of matter ( $m$ ), is equivalent to a certain amount of energy  $E$ . The relationship is given by Einstein's equation:

$$E = mc^2,$$

where  $c$  is the velocity of light. If  $m$  is in grams,  $c$  in centimeters per second,  $E$  is in ergs. If the mass,  $M_0$ , is at rest, the "rest energy" is

$$E = M_0 c^2.$$

*Fission, nuclear.* The splitting of an atomic nucleus into fragments.

*Gamma rays.* Rays of the electromagnetic spectrum, emitted by many radioactive substances.

They travel with the velocity of light and are not deviated by magnetic or electric fields.

Their wavelengths are in general shorter than ordinary x-rays.

*Half-life.* The time, applied to radioactive elements, required for one-half of the initial number of atoms to disintegrate.

*Interaction, radiation with matter.* The effect produced by a "collision" between the radiation and the atom. With x-rays the usual effect is ionization. With neutrons the interaction may be of several types: (1) *scattering*, either elastic, in which kinetic energy is conserved, or inelastic, in which some energy goes into nuclear excitation; (2) *radioactive capture*, simple absorption of the neutron with the subsequent emission of a gamma ray, schematically designated  $(n, \gamma)$ ; and (3) *nuclear disintegration*, absorption of a neutron with subsequent emission of a proton  $(n, p)$ , the emission of two or more neutrons  $(n, 2n)$ , or the splitting or fission of the nucleus  $(n, \text{FP}, \text{FP}, n)$ .

*Ionization.* The removal of one or more orbital electrons from an atom. The ionized atom is called a positive ion. If an electron attaches itself to a neutral atom, a negative ion results. Ionization may be produced by alpha rays, beta rays, x-rays, etc.

*Isobar.* An element having the same mass number,  $A$ , as another element, but a different atomic number,  $Z$ .  ${}_{51}\text{Sb}^{123}$ — ${}_{52}\text{Te}^{123}$ ,  $\text{Sb}^{123}$ ,  $\text{Te}^{123}$ , and  $\text{K}^{40}$ ,  $\text{Ca}^{40}$  are isobars.

*Isometric transition.* A transition in which the atomic number does not change and in which only a gamma ray is emitted from the nucleus or a conversion electron from the atom. The nucleus thus changes from an excited energy state to a state of lower energy.

*Isotone.* One of several nuclei containing the same number of neutrons.

*Isotope.* An atom with the same nuclear charge or atomic number,  $Z$ , as another atom, but a different mass number,  $A$ . Isotopes thus have the same chemical properties and are in the same place in the atomic periodic table.

*Mass defect.* The deviation of the true mass of an atom from the sum of the free masses of its constituents. It represents the total binding energy of all the particles in the nucleus. Binding energy equals mass defect times  $c^2$ .

*Mass number.* The integer atomic weight on a scale where the most prevalent oxygen isotope has a weight of 16. The mass number indicates the total number of protons plus neutrons in the nucleus. Symbol:  $A$ .

*Mass unit.* The rest energy of a particle of unit atomic weight (one-sixteenth the mass of an ordinary oxygen atom), equal to  $1.6603 \times 10^{-24}$  gm. Annihilation energy of 1 mass unit = 931 Mev.

*Meson.* A new type of charged particle found in cosmic rays and having a mass intermediate between that of the proton and electron, i.e., about 200 times that of the electron. The charge may be of either sign.

*MeV.* Symbol for million electron volts, the energy required to move unit electronic charge through a difference of potential of one million volts ( $1.602 \times 10^{12}$  ergs).

*Moderator.* A substance of low atomic weight (deuterium in heavy water, beryllium, carbon) used as a means of slowing down neutrons to a speed at which capture by another nucleus is most probable.

*N unit, for fast neutrons.* An arbitrary unit used to measure neutrons. It is the ionization produced by fast neutrons in a 100-r bakelite-walled Victoreen thimble chamber which exhibits 1 electrostatic unit of charge per cc. of standard air (i.e., 1 r as shown on the scale of the instrument). This dose is often called 1 n.

*Neptunium.* A new chemical element not known to occur in nature, having  $Z = 93$ ,  $A = 237$ . It is formed by radioactive disintegration of  $\text{U}^{239}$ , which emits a  $\beta$  particle to become  $\text{Np}^{239}$ . Neptunium emits beta rays.

*Neutrino.* A particle which has escaped detection, but has been postulated to "balance the books" on missing energy in some disintegrations in which the energies of the emitted electrons do not account for the total energy expected. It must have much less mass than the electron and no charge. It is, therefore, perhaps impossible to detect.

*Neutron.* One of the basic particles of atomic nuclei, having no electric charge and a mass of  $1.6603 \times 10^{-24}$  gm. It has almost exactly the same mass as the proton. In mass units the neutron is 1.00893 and the proton, 1.00758.

*n.* A common name given to the proton and the neutron.

*k.* The compact central portion of an atom, roughly spherical in shape and with a radius about  $10^{-12}$  cm. The nucleus is characterized by the number of its positive charges (atomic number  $Z$ ) and its mass number,  $A$ . The nucleus contains about 99.97 per cent the mass of the atom. The nucleus is surrounded by  $Z$  negative electrons which balance its charge.

*h.* A "particle" of electromagnetic radiation. The energy of the photon quantum determines the type of radiation that it is. Thus, a red light photon has a small amount of energy, a violet light photon more, and an x-ray photon still more. A beam of light or x-rays may be considered as a stream of photons.

*chain reaction.* Any arrangement involving lumps of fissionable material (e.g., uranium), together with a moderator, so arranged as to utilize the fission neutrons sufficiently to result in a chain reaction.

*neptunium.* A new chemical element not known to occur in nature, having  $Z = 94$ ,  $A = 239$ . It is formed by the emission of a B-particle from  $\text{Np}^{239}$ . It is an alpha ray emitter.

*Poisson's distribution law.* This law is of value in determining the observational uncertainty when counting a large number of random events, as is done with a Geiger-Müller counter in radioactivity measurements. Under these conditions the counting of  $N$  events will involve a root mean square error of  $\sqrt{N}$ , or a probable error of  $0.67 \sqrt{N}$ . The statistical error in counting  $A$  events against a background of  $B$  events will be proportional to  $\sqrt{A + 2B}$ .

*positron.* The smallest particle of positive electricity. It has the same mass as the electron, and its positive charge is just equal in magnitude to the negative charge on the electron. Positrons are short-lived because there are always loosely bound electrons in matter which are available to neutralize them.

*proton.* The nucleus of the hydrogen atom. Protons are basic constituent particles of atomic nuclei. They have a positive charge numerically equal to that of the negative electron. The mass of the proton is 1.00758 mass units, almost equal to that of the neutron.

*radioactivity.* The property possessed by certain elements, of spontaneously emitting alpha, beta or gamma rays, by the disintegration of their nuclei.

*resonance reaction.* The capture by a nucleus of a neutron having its energy of bombardment almost exactly equal to the difference between two energy levels in the "compound" nucleus. Reactions of this type occur only for discrete neutron energies. Generally speaking,  $\alpha$ ,  $\beta$ ,  $\gamma$  reactions are "resonance reactions."

*roentgen (r).* A unit of energy dissipation, by gamma or x-rays, in air. It is "that quantity of gamma or gamma-radiation such that the corpuscular emission per 0.001293 gm. of air, produces, in air, ions carrying 1 electrostatic unit of quantity of electricity of either sign." The mass of air referred to is 1 ml. of dry air at 0°C. and 760 mm. Hg pressure. One roentgen produces  $1.61 \times 10^{12}$  ion pairs per gram of air and corresponds to the absorption of  $5.24 \times 10^{13}$  electron volts of energy (83.8 ergs) per gram of air. Symbol: r.

*roentgen-equivalent-man (rem).* The equivalence in tissue ionization in man, of fast neutrons and of gamma rays resulting in the same relative biological effectiveness. One rem is the estimated amount of energy absorbed in tissue which is biologically equivalent in man to roentgen of gamma or x-rays.

$$1 \text{ rem} = \frac{83}{\text{relative biological effectiveness}} \text{ erg per gram of tissue}^{\frac{1}{2}}$$

The relative biological effectiveness for fast neutrons to gamma rays is taken as about 10 for general effects on mammals.

*roentgen-equivalent-physical (rep).* When tissue ionization is produced by any primary radiation other than photons (alpha rays, beta rays, neutrons or protons), the doses may not be expressed in roentgens. Then if the energy lost by ionization in the tissues is the same as the energy loss for 1 roentgen of gamma radiation absorbed in air, the dose is spoken of as 1 roentgen-equivalent-physical (rep).  $1 \text{ rep} = 83 \text{ ergs per gram of tissue}$ .

*roentgen-per-hour-at-one-meter (rh.m.).* A physical unit of strength of a radioactive source which emits gamma rays. Thus one rh.m. of  $\text{Co}^{60}$ , for example, is that amount of  $\text{Co}^{60}$  whose unfiltered gamma ray emission produces 1 roentgen per hour of ionization in air at a distance of 1 meter from the source. If the source were filtered so that the gamma radiation produced 0.5r per hour at 1 meter, then the effective radioactive source strength would be 0.5 rh.m.

*Rutherford rd.* That amount of any radioactive substance which disintegrates at the rate of  $10^{10}$  disintegrations per second. One rd =  $\frac{1}{37}$  millicurie of Rn, Po, etc.

*Specific activity.* The relative number of radioactive atoms of an isotope to the total number of atoms of the isotope in a given preparation.

*Thermal neutron.* A neutron of relatively low energy or low speed. Its energy may be as low as that of an electron volt.

*Tolerance dose.* The total amount of radiation that a person may receive day after day without demonstrable damage to the tissues including the blood and reproductive organs. The tolerance dose for x-rays and radium recommended at the Fifth International Congress of Radiology, for whole body radiation, was 0.1 roentgen per day.

*Tracer.* A small amount of a radioactive isotope mixed with the stable atoms acts as a means of tagging the atoms. If these atoms, in a compound if necessary, are fed to, or injected into, an animal, their subsequent metabolism or disposition may be traced from their radioactivity. The radioactive atoms are indistinguishable by the body from their non-radioactive isotopes, and therefore chemical reactions are not altered. The tracer technic is extremely sensitive, so that only small amounts of radioactive tracer elements are required in many cases.

*Transmutation.* The conversion of one element into another.

*Z.* Symbol for atomic number; the number of positive charges in the nucleus. The properties of an element depend upon Z, which varies from 1 for hydrogen to 94 for curium.

## Chapter 74

### LIFE AND ACTUARIAL TABLES

TABLE change in the actuarial tables used by life insurance companies was in 1947. The old American Experience Table of Mortality, which first appeared in 1868, was replaced by a new table based on more recent experience, primarily on the experience during the decade 1930-1940 of sixteen life insurance companies. This table (Table 402) does not actually reflect current life insurance experience, since the rates of mortality include adjustments which are considered sufficient to provide "reasonable margins in mortality and for contingencies." However, the underlying experience table, excluding these margins, which is known as the 1930-1940 Experience Table, is also available (Table 403).

The most recent life tables presented by the U. S. Bureau of Vital Statistics are compiled from data obtained in the sixteenth census. These figures are based on the 1940 census of population and the deaths of the three-year period 1937-1939. Tables for the total population (Table 404) and for the total white population (Table 405) give the mortality and average future life expectancy at various ages.

## MISCELLANEOUS DATA

TABLE 403

COMMISSIONERS 1941 STANDARD ORDINARY MORTALITY TABLE

Age	Number Living	Number Dying	Rate of Mortality	Age	Number Living	Number Dying	Rate Mortality
1	1,000,000	5770	0.00577	51	800,910	10,628	0.01328
2	994,230	4116	0.00414	52	790,282	11,301	0.01431
3	990,114	3347	0.00338	53	778,981	12,020	0.01543
4	986,767	2960	0.00299	54	766,961	12,779	0.01666
5	983,817	2715	0.00276	55	754,191	13,560	0.01800
6	981,102	2561	0.00261	56	740,631	14,390	0.01957
7	978,541	2417	0.00247	57	726,241	15,252	0.02099
8	976,124	2265	0.00231	58	710,990	16,147	0.02271
9	973,869	2065	0.00212	59	694,843	17,072	0.02458
10	971,804	1914	0.00197	60	677,771	18,022	0.02659
11	969,890	1852	0.00191	61	659,749	18,988	0.02875
12	968,038	1859	0.00192	62	640,761	19,979	0.03103
13	966,179	1913	0.00198	63	620,782	20,958	0.03347
14	964,266	1996	0.00207	64	599,824	21,942	0.03607
15	962,270	2069	0.00215	65	577,882	22,907	0.03946
16	960,201	2103	0.00219	66	554,975	23,842	0.04295
17	958,098	2156	0.00225	67	531,133	24,730	0.04656
18	955,942	2199	0.00230	68	506,403	25,633	0.05063
19	953,743	2260	0.00237	69	480,850	26,502	0.05511
20	951,483	2312	0.00243	70	454,548	26,955	0.05952
21	949,171	2382	0.00251	71	427,593	27,481	0.06441
22	946,789	2452	0.00259	72	400,112	27,872	0.06979
23	944,337	2531	0.00268	73	372,240	28,104	0.07570
24	941,806	2609	0.00277	74	344,136	28,154	0.08181
25	939,197	2705	0.00288	75	315,982	28,009	0.08882
26	936,492	2800	0.00299	76	287,973	27,651	0.09636
27	933,692	2904	0.00311	77	260,322	27,071	0.10399
28	930,788	3025	0.00325	78	233,251	26,262	0.11227
29	927,763	3154	0.00340	79	206,989	25,224	0.12181
30	924,609	3292	0.00356	80	181,765	23,966	0.13181
31	921,317	3437	0.00373	81	157,799	22,502	0.14266
32	917,880	3598	0.00392	82	135,297	20,857	0.15411
33	914,282	3767	0.00412	83	114,440	19,082	0.16671
34	910,515	3961	0.00435	84	95,378	17,167	0.17981
35	906,554	4161	0.00459	85	78,221	15,183	0.19401
36	902,393	4386	0.00486	86	63,036	13,198	0.20931
37	898,007	4625	0.00515	87	49,838	11,245	0.22561
38	893,382	4878	0.00546	88	38,593	9378	0.24301
39	888,504	5162	0.00581	89	29,215	7638	0.26141
40	883,342	5459	0.00618	90	21,577	6063	0.28091
41	877,883	5785	0.00659	91	15,514	4681	0.30171
42	872,098	6131	0.00703	92	10,833	3506	0.32381
43	865,967	6503	0.00751	93	7327	2540	0.34661
44	859,464	6910	0.00804	94	4787	1776	0.37111
45	852,554	7340	0.00861	95	3011	1193	0.39621
46	845,214	7801	0.00923	96	1818	813	0.44711
47	837,413	8299	0.00991	97	1005	551	0.54821
48	829,114	8822	0.01064	98	454	329	0.72461
49	820,292	9392	0.01145	99	125	125	1.0000
50	810,900	9990	0.01232				

## LIFE AND ACTUARIAL TABLES

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TABLE 404

ATED ANNUAL RATE OF MORTALITY PER 1000 BASED ON EXPERIENCE 1930-1940

Age	Rate of Mortality	Age	Rate of Mortality
	5.01	51.....	19.79
	3.37	52.....	11.74
	2.60	53.....	12.97
	2.20	54.....	14.09
	1.96	55.....	15.40
	1.80	56.....	16.82
	1.64	57.....	18.34
	1.47	58.....	19.97
	1.27	59.....	21.76
	1.11	60.....	23.69
	1.03	61.....	25.81
	1.03	62.....	28.10
	1.09	63.....	30.58
	1.19	64.....	33.25
	1.30	65.....	36.13
	1.39	66.....	39.23
	1.47	67.....	42.56
	1.52	68.....	46.15
	1.59	69.....	50.04
	1.67	70.....	54.25
	1.76	71.....	58.79
	1.84	72.....	63.71
	1.89	73.....	69.02
	1.95	74.....	74.80
	2.01	75.....	81.05
	2.04	76.....	87.82
	2.09	77.....	95.17
	2.11	78.....	103.12
	2.16	79.....	111.74
	2.22	80.....	121.06
	2.29	81.....	131.14
	2.38	82.....	142.06
	2.50	83.....	153.70
	2.63	84.....	166.01
	2.79	85.....	178.98
	2.97	86.....	192.53
	3.20	87.....	206.72
	3.46	88.....	222.76
	3.74	89.....	241.86
	4.06	90.....	265.23
	4.41	91.....	294.08
	4.80	92.....	329.62
	5.23	93.....	373.06
	5.71	94.....	425.61
	6.24	95.....	488.49
	6.81	96.....	562.89
	7.44	97.....	650.03
	8.15	98.....	751.12
	8.92	99.....	867.38
	9.76	100.....	1000.00

TABLE 405

LIFE TABLE FOR THE TOTAL POPULATION OF THE UNITED STATES: 1939-1941

<i>Year of Age</i>	<i>Mortality Rate</i>	<i>Of 100,000 Born Alive</i>		<i>Stationary Population</i>		<i>Average Future Lifetime</i>
<i>Period of Life between Two Exact Ages Stated</i>	<i>Number Dying per 1000 Alive at Beginning of Year of Age</i>	<i>Number Living at Beginning of Year of Age</i>	<i>Number Dying During Year of Age</i>	<i>In Year of Age</i>	<i>In Year of Age and All Later Years</i>	<i>Average Number of Years of Life Remaining at Beginning of Year of Age</i>
0-1 .....	47.10	100,000	4710	96,058	6,362,494	63.62
1-2 .....	5.21	95,290	496	94,997	6,266,436	65.76
2-3 .....	2.67	94,794	254	94,660	6,171,439	65.10
3-4 .....	1.88	94,540	177	94,448	6,076,779	64.28
4-5 .....	1.51	94,363	143	94,288	5,982,331	63.40
5-6 .....	1.32	94,220	125	94,157	5,888,043	62.49
6-7 .....	1.17	94,095	110	94,041	5,793,886	61.57
7-8 .....	1.05	93,985	98	93,936	5,699,845	60.65
8-9 .....	0.96	93,887	91	93,841	5,605,909	59.71
9-10 .....	0.91	93,796	86	93,754	5,512,068	58.77
10-11 .....	0.90	93,710	84	93,668	5,418,314	57.82
11-12 .....	0.92	93,626	86	93,583	5,324,646	56.87
12-13 .....	0.97	93,540	91	93,495	5,231,063	55.92
13-14 .....	1.07	93,449	100	93,399	5,137,568	54.98
14-15 .....	1.22	93,349	114	93,292	5,044,169	54.04
15-16 .....	1.39	93,235	130	93,170	4,950,877	53.10
16-17 .....	1.57	93,105	146	93,031	4,857,707	52.17
17-18 .....	1.73	92,959	162	92,878	4,764,676	51.26
18-19 .....	1.88	92,797	174	92,711	4,671,798	50.34
19-20 .....	2.03	92,623	188	92,529	4,579,087	49.44
20-21 .....	2.17	92,435	201	92,334	4,486,558	48.54
21-22 .....	2.30	92,234	212	92,128	4,394,224	47.64
22-23 .....	2.42	92,022	223	91,911	4,302,096	46.75
23-24 .....	2.50	91,799	229	91,684	4,210,185	45.86
24-25 .....	2.56	91,570	235	91,452	4,118,501	44.98
25-26 .....	2.62	91,335	239	91,216	4,027,049	44.09
26-27 .....	2.67	91,096	243	90,974	3,935,833	43.21
27-28 .....	2.75	90,853	250	90,728	3,844,859	42.32
28-29 .....	2.85	90,603	258	90,473	3,754,131	41.44
29-30 .....	2.95	90,345	267	90,212	3,663,658	40.55
30-31 .....	3.07	90,078	276	89,939	3,573,446	39.67
31-32 .....	3.20	89,802	288	89,658	3,483,507	38.79
32-33 .....	3.35	89,514	299	89,365	3,393,849	37.91
33-34 .....	3.51	89,215	313	89,058	3,304,484	37.04
34-35 .....	3.69	88,902	329	88,737	3,215,426	36.17
35-36 .....	3.90	88,573	345	88,401	3,126,689	35.30
36-37 .....	4.12	88,228	363	88,047	3,038,288	34.44
37-38 .....	4.36	87,865	383	87,674	2,950,241	33.58
38-39 .....	4.62	87,482	404	87,279	2,862,567	32.72
39-40 .....	4.91	87,078	428	86,864	2,775,288	31.87
40-41 .....	5.24	86,650	454	86,423	2,688,424	31.03

Rates of mortality at ages above 87 are not based on actual statistics at these ages, but have been obtained by mathematical extrapolation from mortality rates at younger ages. Other life table functions at these ages are based on the extrapolated rates of mortality, and may not necessarily represent actual conditions.

TABLE 405—Continued

Year of Age	Mortality Rate	Of 100,000 Born Alive		Stationary Population		Average Future Lifetime
Period of Life between Two Exact Ages Stated	Number Dying per 1000 Alive at Beginning of Year of Age	Number Living at Beginning of Year of Age	Number Dying During Year of Age	In Year of Age	In Year of Age and All Later Years	Average Number of Years of Life Remaining at Beginning of Year of Age
42	5.59	86,196	482	85,955	2,602,001	30.19
43	5.99	85,714	513	85,458	2,516,046	29.35
44	6.43	85,201	548	84,927	2,430,588	28.53
45	6.91	84,653	584	84,361	2,345,661	27.71
46	7.44	84,069	626	83,756	2,261,300	26.90
47	8.01	83,443	668	83,109	2,177,544	26.10
48	8.62	82,775	714	82,418	2,094,435	25.30
49	9.28	82,061	761	81,680	2,012,017	24.52
50	9.99	81,300	813	80,894	1,930,337	23.74
51	10.76	80,487	866	80,054	1,849,443	22.98
52	11.59	79,621	923	79,160	1,769,389	22.22
53	12.49	78,698	982	78,206	1,690,229	21.48
54	13.46	77,716	1047	77,193	1,612,023	20.74
55	14.51	76,669	1112	76,113	1,534,830	20.02
56	15.64	75,557	1182	74,966	1,458,717	19.31
57	16.84	74,375	1252	73,750	1,383,751	18.60
58	18.12	73,123	1325	72,460	1,310,001	17.92
59	19.49	71,798	1400	71,098	1,237,541	17.24
60	20.95	70,398	1474	69,661	1,166,443	16.57
61	22.51	68,924	1552	68,148	1,096,782	15.91
62	24.19	67,372	1630	66,557	1,028,634	15.27
63	26.01	65,742	1710	64,887	962,077	14.63
64	27.97	64,032	1791	63,137	897,190	14.01
65	30.12	62,241	1875	61,304	834,053	13.40
66	32.48	60,366	1960	59,386	772,749	12.80
67	35.09	58,406	2050	57,381	713,363	12.21
68	37.98	56,356	2140	55,286	655,982	11.64
69	41.20	54,216	2234	53,099	600,696	11.08
70	44.77	51,982	2327	50,818	547,597	10.53
71	48.73	49,655	2420	48,445	496,779	10.00
72	53.12	47,235	2509	45,981	448,334	9.49
73	57.98	44,726	2593	43,430	402,353	9.00
74	63.33	42,133	2668	40,799	358,923	8.52
75	69.18	39,465	2730	38,100	318,124	8.06
76	75.54	36,735	2775	35,347	280,024	7.62
77	82.39	33,960	2798	32,561	244,677	7.20
78	89.75	31,162	2797	29,763	212,116	6.81
79	97.61	28,365	2769	26,981	182,353	6.43
80	105.99	25,596	2713	24,240	155,372	6.07
81	114.91	22,883	2629	21,568	131,132	5.73
82	124.38	20,254	2519	18,995	109,564	5.41
83	134.44	17,735	2385	16,542	90,569	5.11
84	145.08	15,350	2226	14,237	74,027	4.82
85	156.25	13,124	2051	12,099	59,790	4.56
86	167.88	11,073	1859	10,143	47,691	4.31
87	179.92	9214	1658	8385	37,548	4.08
88	192.29	7556	1453	6830	29,163	3.86

## MISCELLANEOUS DATA

TABLE 405—*Continued*

<i>Year of Age</i>	<i>Mortality Rate</i>	<i>Of 100,000 Born Alive</i>		<i>Stationary Population</i>		<i>Average For Life</i>
<i>Period of Life between Two Exact Ages Stated</i>	<i>Number Dying per 1000 Alive at Beginning of Year of Age</i>	<i>Number Living at Beginning of Year of Age</i>	<i>Number Dying During Year of Age</i>	<i>In Year of Age</i>	<i>In Year of Age and All Later Years</i>	<i>Average Number of Years Life Remaining at Beginning of Year of Age</i>
88-89.....	204.93	6103	1250	5478	22,333	3.66
89-90.....	217.79	4853	1057	4324	16,855	3.47
90-91.....	230.81	3796	876	3358	12,531	3.30
91-92.....	243.94	2920	713	2563	9173	3.14
92-93.....	257.11	2207	567	1924	6610	2.99
93-94.....	270.31	1640	443	1418	4686	2.86
94-95.....	283.44	1197	340	1027	3268	2.73
95-96.....	296.46	857	254	730	2241	2.61
96-97.....	309.35	603	186	510	1511	2.50
97-98.....	322.10	417	135	350	1001	2.40
98-99.....	334.75	282	94	235	651	2.31
99-100.....	347.36	188	65	155	416	2.21
100-101.....	360.05	123	45	101	261	2.13
101-102.....	372.98	78	29	64	160	2.04
102-103.....	386.34	49	19	39	96	1.96
103-104.....	400.36	30	12	24	57	1.88
104-105.....	415.25	18	7	15	33	1.80
105-106.....	431.17	11	5	8	18	1.72
106-107.....	448.20	6	3	5	10	1.64
107-108.....	466.33	3	1	2	5	1.56
108-109.....	485.39	2	1	2	3	1.48
109-110.....	505.10	1	1	1	1	1.41

TABLE 406

LIFE TABLE FOR TOTAL WHITE POPULATION IN THE UNITED STATES: 1939-1941

Age of Life Between Two Exact Ages Stated	Mortality Rate	Of 100,000 Born Alive		Stationary Population		Average Future Lifetime
	Number Dy- ing per 1000 Alive at Beginning of Year of Age	Number Living at Beginning of Year of Age	Number Dying During Year of Age	In Year of Age	In Year of Age and All Later Years	Average Num- ber of Years of Life Remain- ing at Begin- ning of Year of Age
1.....	43.15	100,000	4315	96,354	6,492,419	64.92
2.....	4.60	95,685	440	95,425	6,396,065	66.84
3.....	2.43	95,245	231	95,123	6,300,640	66.15
4.....	1.76	95,014	167	94,927	6,205,517	65.31
5.....	1.41	94,847	134	94,777	6,110,590	64.43
6.....	1.24	94,713	118	94,654	6,015,813	63.52
7.....	1.10	94,595	104	94,543	5,921,159	62.59
8.....	1.00	94,491	94	94,444	5,826,616	61.66
9.....	0.92	94,397	87	94,353	5,732,172	60.72
10.....	0.87	94,310	82	94,269	5,637,819	59.78
11.....	0.85	94,228	81	94,187	5,543,550	58.83
12.....	0.86	94,147	81	94,107	5,449,363	57.88
13.....	0.89	94,066	83	94,025	5,355,256	56.93
14.....	0.96	93,983	91	93,937	5,261,231	55.98
15.....	1.07	93,892	100	93,842	5,167,294	55.03
16.....	1.20	93,792	113	93,735	5,073,452	54.09
17.....	1.33	93,679	124	93,617	4,979,717	53.16
18.....	1.45	93,555	136	93,487	4,886,100	52.23
19.....	1.56	93,419	146	93,347	4,792,613	51.30
20.....	1.67	93,273	156	93,195	4,699,266	50.38
21.....	1.78	93,117	166	93,034	4,606,071	49.47
22.....	1.88	92,951	175	92,864	4,513,037	48.55
23.....	1.97	92,776	182	92,685	4,420,173	47.64
24.....	2.03	92,594	189	92,499	4,327,488	46.74
25.....	2.08	92,405	192	92,310	4,234,989	45.83
26.....	2.12	92,213	195	92,115	4,142,679	44.92
27.....	2.16	92,018	199	91,919	4,050,564	44.02
28.....	2.23	91,819	204	91,717	3,958,645	43.11
29.....	2.30	91,615	212	91,509	3,866,928	42.21
30.....	2.39	91,403	218	91,294	3,775,419	41.31
31.....	2.49	91,185	228	91,071	3,684,125	40.40
32.....	2.60	90,957	236	90,839	3,593,054	39.50
33.....	2.73	90,721	248	90,597	3,502,215	38.60
34.....	2.87	90,473	259	90,343	3,411,618	37.71
35.....	3.03	90,214	273	90,077	3,321,275	36.82
36.....	3.20	89,941	288	89,797	3,231,198	35.93
37.....	3.40	89,653	305	89,500	3,141,401	35.04
38.....	3.61	89,348	322	89,187	3,051,901	34.16
39.....	3.85	89,026	343	88,855	2,962,714	33.28
40.....	4.11	88,683	365	88,501	2,873,859	32.41
41.....	4.41	88,318	389	88,123	2,785,358	31.54

Rates of mortality at ages above 92 are not based on actual statistics at these ages, but have been obtained by mathematical extrapolation from mortality rates at younger ages. The life table functions at these ages are based on the extrapolated rates of mortality, and do not necessarily represent actual conditions.

## MISCELLANEOUS DATA

TABLE 406—Continued

<i>Year of Age</i>	<i>Mortality Rate</i>	<i>Of 100,000 Born Alive</i>		<i>Stationary Population</i>		<i>Average Future Lifetime</i>
<i>Period of Life between Two Exact Ages Stated</i>	<i>Number Dying per 1000 Alive at Beginning of Year of Age</i>	<i>Number Living at Beginning of Year of Age</i>	<i>Number Dying During Year of Age</i>	<i>In Year of Age</i>	<i>In Year of Age and All Later Years</i>	<i>Average Number of Years Life Remaining at Beginning of Year of Age</i>
41-42.....	4.74	87,929	416	87,721	2,697,235	30 68
42-43.....	5.11	87,513	447	87,289	2,609,514	29 82
43-44.....	5.52	87,066	480	86,826	2,522,225	28 97
44-45.....	5.97	86,586	517	86,327	2,435,399	28 13
45-46.....	6.46	86,069	557	85,791	2,349,072	27 29
46-47.....	7.00	85,512	598	85,213	2,263,281	26 47
47-48.....	7.59	84,914	645	84,591	2,178,068	25 65
48-49.....	8.22	84,269	693	83,923	2,093,477	24 84
49-50.....	8.90	83,576	743	83,204	2,009,554	24 04
50-51.....	9.64	82,833	799	82,434	1,926,350	23 26
51-52.....	10.45	82,034	857	81,605	1,843,916	22 48
52-53.....	11.32	81,177	919	80,717	1,762,311	21 71
53-54.....	12.28	80,258	985	79,766	1,681,594	20 95
54-55.....	13.31	79,273	1055	78,745	1,601,828	20 21
55-56.....	14.43	78,218	1129	77,653	1,523,083	19 47
56-57.....	15.63	77,089	1205	76,487	1,445,430	18 75
57-58.....	16.92	75,884	1284	75,242	1,368,943	18 04
58-59.....	18.31	74,600	1365	73,918	1,293,701	17 34
59-60.....	19.79	73,235	1450	72,510	1,219,783	16 66
60-61.....	21.40	71,785	1536	71,017	1,147,273	15 98
61-62.....	23.12	70,249	1624	69,437	1,076,256	15 32
62-63.....	24.99	68,625	1715	67,767	1,006,819	14 67
63-64.....	27.01	66,910	1807	66,007	939,052	14 03
64-65.....	29.22	65,103	1902	64,151	873,045	13 41
65-66.....	31.64	63,201	2000	62,201	808,894	12 80
66-67.....	34.33	61,201	2101	60,150	746,693	12 20
67-68.....	37.31	59,100	2206	57,997	686,543	11 62
68-69.....	40.63	56,894	2311	55,739	628,546	11 05
69-70.....	44.31	54,583	2418	53,374	572,807	10 49
70-71.....	48.39	52,165	2524	50,903	519,433	9 96
71-72.....	52.90	49,641	2626	48,328	468,530	9 44
72-73.....	57.88	47,015	2721	45,654	420,202	8 94
73-74.....	63.36	44,294	2807	42,890	374,548	8 46
74-75.....	69.34	41,487	2877	40,049	331,658	7 99
75-76.....	75.83	38,610	2927	37,146	291,609	7 55
76-77.....	82.82	35,683	2955	34,206	254,463	7 13
77-78.....	90.31	32,728	2956	31,249	220,257	6 73
78-79.....	98.32	29,772	2927	28,309	189,008	6 35
79-80.....	106.87	26,845	2869	25,410	160,699	5 99
80-81.....	115.99	23,976	2781	22,585	135,289	5 64
81-82.....	125.73	21,195	2665	19,863	112,704	5 32
82-83.....	136.12	18,530	2522	17,268	92,841	5 01
83-84.....	147.17	16,008	2356	14,830	75,573	4 72
84-85.....	158.85	13,652	2169	12,568	60,743	4 45
85-86.....	171.09	11,483	1964	10,500	48,175	4 20
86-87.....	183.84	9519	1750	8644	37,675	3 96
87-88.....	197.03	7769	1531	7003	29,031	3 74

TABLE 406—Continued

Age Interval of Life Between Two Exact Ages Indicated	Mortality Rate	Of 100,000 Born Alive		Stationary Population		Average Future Lifetime
	Number Dy- ing per 1000 Alive at Beginning of Year of Age	Number Living at Beginning of Year of Age	Number Dying During Year of Age	In Year of Age	In Year of Age and All Later Years	Average Num- ber of Years of Life Remain- ing at Begin- ning of Year of Age
9.....	210.61	6238	1314	5581	22,028	3.53
10.....	224.53	4924	1105	4372	16,447	3.34
11.....	238.74	3819	912	3363	12,075	3.16
12.....	253.20	2907	736	2539	8712	3.00
13.....	267.84	2171	582	1880	6173	2.84
14.....	282.74	1589	449	1364	4293	2.70
15.....	297.77	1140	339	971	2929	2.57
16.....	312.88	801	251	675	1958	2.45
17.....	328.03	550	180	460	1283	2.33
18.....	343.18	370	127	306	823	2.23
19.....	358.27	243	87	199	517	2.13
20.....	373.27	156	58	127	318	2.04
21.....	388.11	98	38	79	191	1.95
22.....	402.76	60	24	48	112	1.88
23.....	417.14	36	15	28	64	1.81
24.....	431.21	21	9	16	36	1.74
25.....	444.89	12	5	9	20	1.68
26.....	458.10	7	3	5	11	1.62
27.....	470.78	4	2	3	6	1.57
28.....	482.81	2	1	2	3	1.53
29.....	494.08	1	1	1	1	1.48

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# APPENDIX

## TABLES OF WEIGHTS, MEASURES AND STANDARDS

### THE METRIC SYSTEM

The meter, unit of length, is the distance between two defining lines on the international prototype meter bar at 0° C. at the International Bureau of Weights and Measures at Sèvres, France. The meter is 39.37 United States standard inches long.

The liter, unit of capacity, is equivalent to the space occupied by 1 kilogram of water at the temperature of its maximum density (4° C., nearly), under standard atmospheric pressure. 1.000027 cubic decimeters.

The gram, unit of mass (weight), is one one-thousandth of the mass of the international prototype kilogram, which was intended to have the same mass as a cubic decimeter of water at the temperature of its maximum density (4° C., nearly), under standard atmospheric pressure.

TABLE 407  
MEASURES OF LENGTH AND SURFACE

Length		
<i>Metric Denominations and Values</i>		<i>Equivalents</i>
1 myriameter.....	10,000 meters	6.2137 miles
1 kilometer.....	1000 meters	0.62137 mile, or 3280 feet, 10 inches
1 hectometer.....	100 meters	328 feet, 1 inch
1 decameter.....	10 meters	39.37 inches
1 meter.....	1 meter	39.37 inches
1 decimeter.....	1/10 meter	3.937 inches
1 centimeter.....	1/100 meter	0.3937 inch
1 millimeter.....	1/1000 meter	0.0394 inch
1 micron.....	1/1,000,000 meter	1/1000 millimeter
1 millimicron.....	1/1,000,000,000 meter	1/1000 micron
1 Angstrom unit.....	1/10 <sup>10</sup> meter	1/10,000 micron
Surface		
1 square kilometer.....	1,000,000 square meters	0.3861 square mile
1 hectare.....	10,000 square meters	2.471 acres: equivalent to a square 328'1" on a side
1 are.....	100 square meters	119.6 square yards
1 centare.....	1 square meter	1550 square inches
1 square decimeter.....	0.01 square meter	15.50 square inches
1 square centimeter.....	0.0001 square meter	0.155 square inch
1 square millimeter.....	0.000001 square meter	0.00155 square inch

TABLE 408  
MEASURES OF CAPACITY AND VOLUME

Metric Denominations	Metric Values	Equivalents		
		Cubic Inches	Dry Measure	Liquid Measure
1 kiloliter	1000 liters	61025.0	1.308 cubic yards	264.18 gallons
1 hectoliter	100 liters	6102.50	2.8378 bushels	26.418 gallons
1 dekaliter	10 liters	610.250	1.1351 pecks	2.6418 gallons
1 liter	1 liter	61.0250	0.9081 quart	1.0567 quarts
1 deciliter	1/10 liter	6.10250	0.18162 pint	0.8454 gill
1 centiliter	1/100 liter	0.610250	0.6102 cubic inch	0.3381 fluidounce
1 milliliter	1/1000 liter	0.0610250	0.0610 cubic inch	0.2705 fluidram

TABLE 409  
MEASURES OF MASS (WEIGHTS)

Metric Denominations	Metric Values	Equivalents		
		Quantity of Water at Standard Pressure and Maximum Density	Avoirdupois Weight	Troy Weight
1 metric ton	1,000,000 grams	1 cubic meter (nearly)	1.102311 short tons	
1 quintal	100,000 grams	1 hectoliter	220.46 pounds	
1 myriagram	10,000 grams	10 liters	22.046 pounds	
1 kilogram or kilo	1000 grams	1 liter	2.2046 pounds	2.6792 pounds
1 hectogram	100 grams	1 deciliter	3.5274 ounces	3.2151 ounces
1 decagram	10 grams	1 centiliter	0.3527 ounce	0.3215 ounce
1 gram	1 gram	1 cubic centimeter	0.0353 ounce	0.0322 ounce
1 decigram	1/10 gram	1/10 cubic centimeter		1.5432 grains
1 centigram	1/100 gram	10 cubic millimeters		0.1543 grain
1 milligram	1/1000 gram	1 cubic millimeter		0.0154 grain

TABLE 410  
DOMESTIC WEIGHTS AND MEASURES

*Liquid Measure*

4 gills.....	1 pint
2 pints.....	1 quart
4 quarts.....	1 gallon
31 ½ gallons.....	1 barrel
2 barrels.....	1 hogshead

(A standard U.S. gallon, the unit of liquid measure, is the same as the English wine gallon and contains 231 cubic inches. A gallon of water weighs about 8 ⅓ pounds. A barrel contains about 4 ⅕ cubic feet.)

*Apothecaries' Fluid Measure*

60 minims.....	1 fluidram
8 fluidrams.....	1 fluidounce
16 fluidounces.....	1 pint
8 pints.....	1 gallon

*Apothecaries' Weight*

20 grains.....	1 scruple
3 scruples.....	1 dram
8 drams.....	1 ounce
12 ounces.....	1 pound

*Avoirdupois Weight*

16 drams.....	1 ounce (437 ½ grains)
16 ounces.....	1 pound (7000 grains)
25 pounds.....	1 quarter
4 quarters, or 100 pounds.....	1 short hundredweight
112 pounds.....	1 long hundredweight
20 hundredweight.....	1 ton
2000 pounds (20 short hundredweight).....	1 short ton
2240 pounds (20 long hundredweight).....	1 long ton

*Troy Weight*

24 grains.....	1 pennyweight
20 pennyweights.....	1 ounce (480 grains)
12 ounces.....	1 pound (5760 grains)
3 ⅙ grains.....	1 carat

(The metric carat, 200 milligrams, is now generally used by jewelers.)

*Angular Measure*

60 seconds (").....	1 minute (')
60 minutes.....	1 degree (°)
90 degrees.....	1 right angle, or quadrant
360 degrees.....	1 circle, or circumference
1 radian.....	57.296° —

TABLE 411

## METRIC AND APOTHECARIES' EQUIVALENTS\*

*Metric Weights**Apothecaries' Weights**Metric Weights*

Grams	Grains	Milligrams
0.0001	1/640	0.1
0.0002	1/320	0.2
0.0003	1/210	0.3
0.000324	1/200	0.324
0.0004	1/160	0.4
0.000432	1/150	0.432
0.0005	1/128	0.5
0.00054	1/120	0.54
0.0006	1/100	0.6
0.0008	1/80	0.8
0.001	1/64	1.0
0.0011	1/60	1.1
0.0013	1/50	1.3
0.0016	1/40	1.6
0.0018	1/36	1.8
0.0022	1/30	2.2
0.0026	1/25	2.6
0.0032	1/20	3.2
0.004	1/16	4.0
0.0065	1/10	6.5
0.0072	1/9	7.2
0.0081	1/8	8.1
0.0092	1/7	9.2
0.011	1/6	11.0
0.013	1/5	13.0
0.0162	1/4	16.2
0.0217	1/3	21.7
0.0243	3/8	24.3
0.0324	1/2	32.4
0.0432	2/3	43.2
0.0486	3/4	48.6
0.065	1	65.0

*Metric Weights  
or Measures**Apothecaries'  
Weights**Apothecaries'  
Measures*

Grams or CC.	Grains	Minims of Water at 4° C
0.0648	1	1.0518
0.13	2	2.11
0.194	3	3.15
0.259	4	4.20
0.324	5	5.26
0.389	6	6.31
0.454	7	7.37
0.5	7.72	8.12
0.518	8	8.41
0.583	9	9.46
0.648	10	10.52
0.713	11	11.57
0.778	12	12.63
0.842	13	13.67
0.907	14	14.72
0.972	15	15.78
1.000	15.4324	16.23
1.296	20	21.04
1.944	30	31.55

\* These tables conform to the regulations of the United States Pharmacopoeia, which are substantially as follows: Approximate equivalents may be used when prepared dosage forms, such as tablets, capsules and ampules, are dispensed. When it is necessary to convert specific quantities of a prescription or pharmaceutical formula, exact equivalents should be used.

TABLE 412  
USEFUL EQUIVALENTS—WEIGHTS AND MEASURES

Weights		
<i>Apothecaries'</i>	<i>Apothecaries'</i>	<i>Metric</i>
1 scruple.....	20 grains	1.296 gm.
1 dram.....	60 grains	3.88 gm.
1 ounce.....	480 grains (8 drams)	31.1 gm.
1 pound.....	5760 grains (12 ounces)	373.24 gm.
<i>Metric</i>	<i>Apothecaries'</i>	<i>Metric</i>
1 milligram.....	1/65 grain*	0.001 gm.
1 centigram.....	1/6 grain*	0.01 gm.
1 decigram.....	1 1/2 grain*	0.1 gm.
1 gram.....	15.432 grains	0.001 kilogram
1 kilogram.....	2.2 pounds avdp.*	1000 gm.
<i>Avoirdupois</i>	<i>Apothecaries'</i>	<i>Metric</i>
1 ounce.....	437.5 grains	28.35 gm.
1 pound.....	7000 grains	453.59 gm.
1 ton.....	2000 pounds	907.184 kilograms

Liquid Measures		
<i>Avoirdupois</i>	<i>Apothecaries'</i>	<i>Metric</i>
1 fluidram.....	60 minims	3.697 cc.
1 fluidounce.....	8 fluidrams	29.573 cc.
1 pint.....	16 fluidounces	473.167 cc.
1 quart.....	32 fluidounces	946.333 cc.
1 gallon.....	128 fluidounces	3785 cc.
<i>Metric</i>	<i>Cubic Measure</i>	<i>Metric</i>
1 milliliter.....	0.061 cubic inch	1 cc.
1 centiliter.....	0.61 cubic inch	10 cc.
1 deciliter.....	6.1 cubic inches	100 cc.
1 liter.....	61.0271 cubic inches	1000 cc.
1 teaspoonful.....	1 fluidram	4 cc.*
1 dessertspoonful.....	2 fluidrams	8 cc.*
1 tablespoonful.....	4 fluidrams	15 cc.*
1 wineglassful.....	2 fluidounces	60 cc.*
1 teacupful.....	4 fluidounces	120 cc.*
1 glassful.....	8 fluidounces	240 cc.*

Linear Measures		
1 inch.....	25.4 mm.	2.54 centimeters
1 foot.....	12 inches	30.48 centimeters
1 yard.....	36 inches	0.9144 meter
1 rod.....	198 inches (16 1/2 feet)	5.029 meters
1 mile.....	5280 feet	1.609 kilometers
1 mm.....	0.03937 inch	1000 microns
1 centimeter.....	0.3937 inch	10 mm.
1 decimeter.....	3.937 inches	10 centimeters
1 meter.....	39.37 inches	10 decimeters
1 kilometer.....	3281 feet (0.62 mile)	1000 meters

\* Approximate equivalent.

TABLE 413  
TEMPERATURE EQUIVALENTS

Centigrade.....	-40	-30	-20	-10	0	10	20	30	40	50	100
Fahrenheit.....	-40	-22	-4	14	32	50	68	86	104	122	212
Réaumur.....	-32	-24	-16	-8	0	8	16	24	32	40	80

1° F. =  $\frac{5}{9}$ ° C.

1° R. =  $\frac{4}{5}$ ° C.

Absolute zero of temperature = 273.1°

□ Values represent freezing point of water.

○ Values represent boiling point of water.

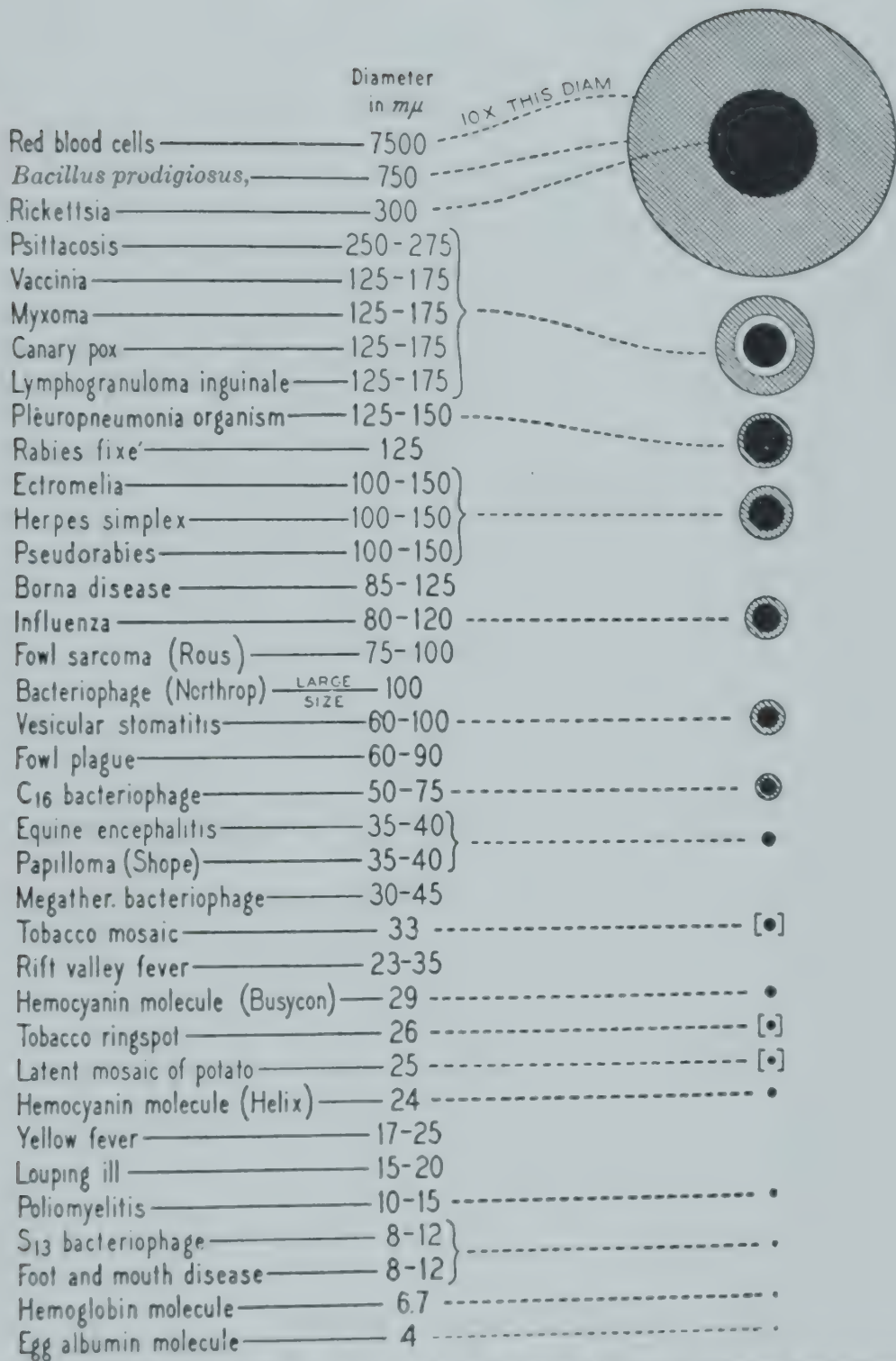


Fig. 237. A chart showing the relative sizes of several selected viruses, including bacteriophages, as compared to those of the red blood cells, *Bacillus prodigiosus*, rickettsia, pleuropneumonia organism and protein molecules. (Stanley, American Naturalist, vol. 72.)



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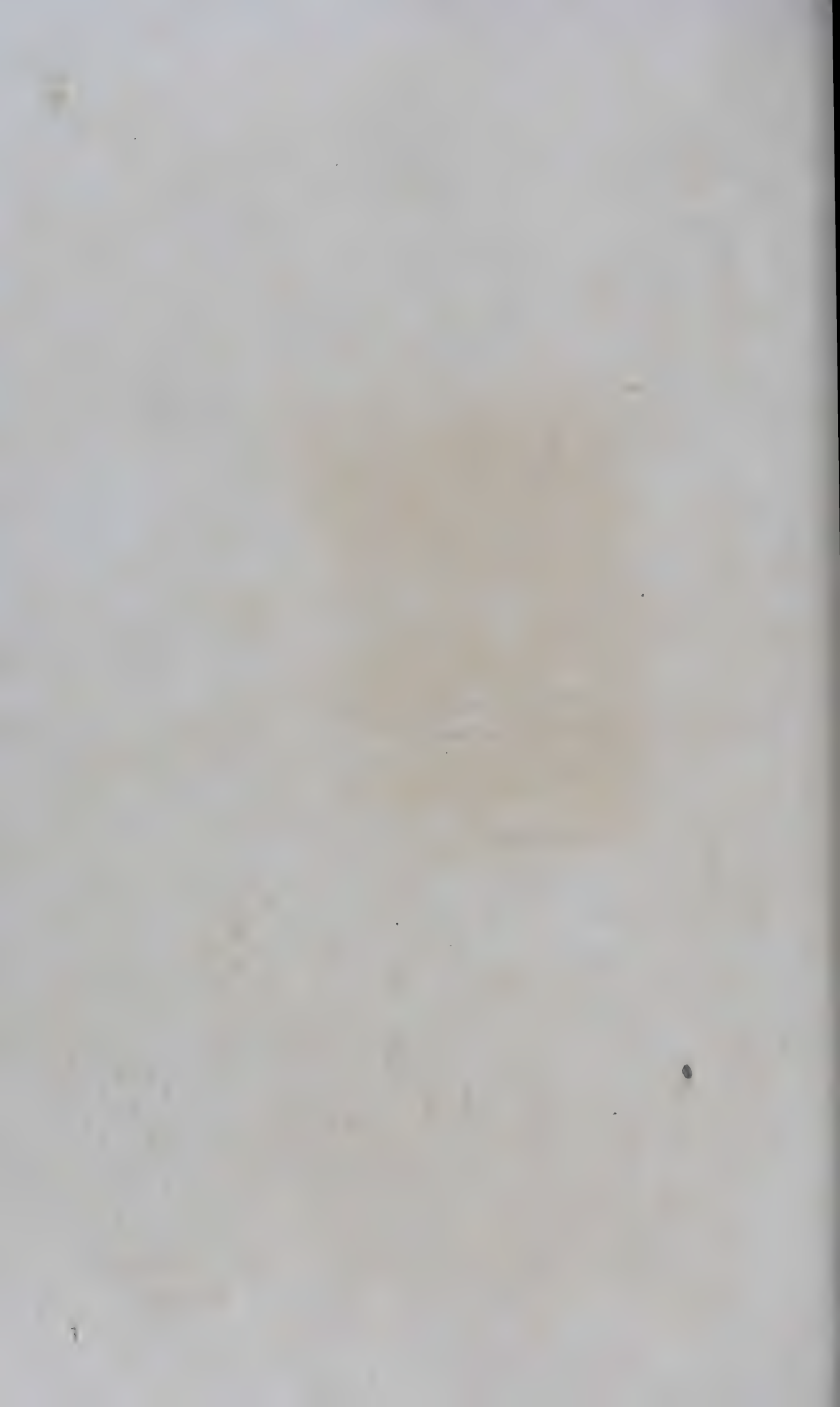
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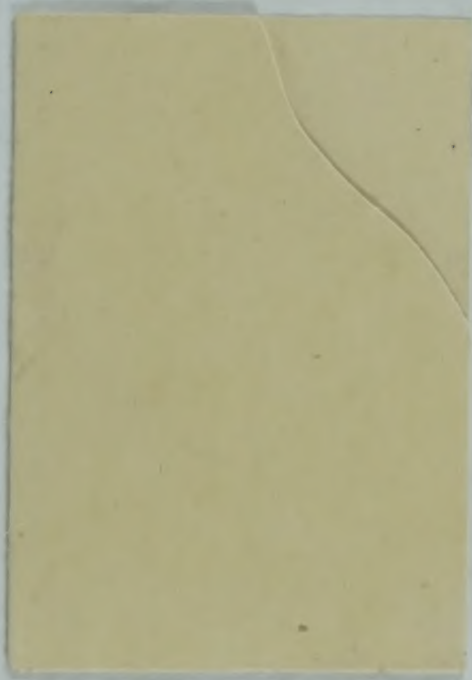
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